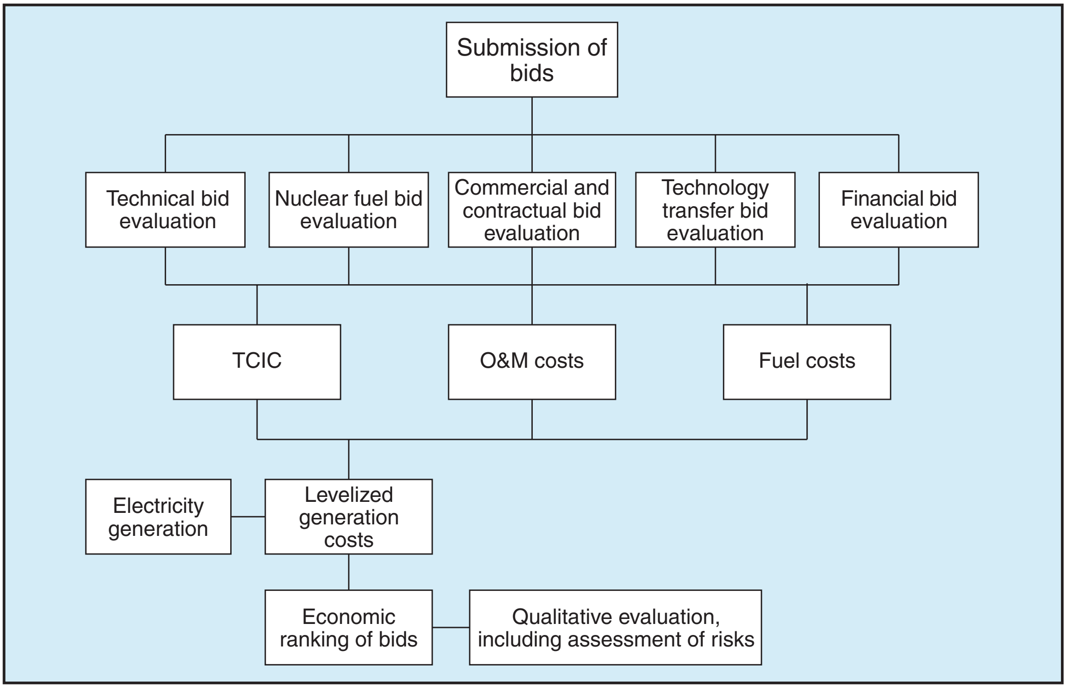

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Economic Evaluation of Bids for Nuclear Power Plants 1999 Edition

INTERNATIONAL ATOMIC ENERGY AGENCY, VIENNA, 2000

ECONOMIC EVALUATION OF BIDS
FOR NUCLEAR POWER PLANTS
1999 EDITION

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FOREWORD

The IAEA has prepared and published a series of technical reports to assist Member States, particularly those which are developing countries, in making comprehensive assessments for the deployment of nuclear power. A number of the reports deal specifically with the bidding for and bid evaluation of nuclear power plants, i.e. Bid Invitation Specifications for Nuclear Power Plants (1987); Technical Evaluation of Bids for Nuclear Power Plants (1981); and Economic Evaluation of Bids for Nuclear Power Plants (1986). The latter publication is a revised version of the 1976 report bearing the same title.

The 1986 edition of the guidebook on the Economic Evaluation of Bids for Nuclear Power Plants has been widely distributed to Member States in order to facilitate economic and financial bid evaluation. It has been used as a basic textbook for international, regional and national training courses and workshops on the subject. Since the guidebook was last revised, substantial experience and feedback have been gained through its use by Member States. Additionally, the bidding approaches, contracting processes and financing arrangements for nuclear power projects have become greatly diversified, and computer technology and software have undergone significant development. In view of these developments, the contents, data and computer program given in the 1986 edition guidebook have become outdated. Consequently, the IAEA decided in November 1996 to update both the guidebook and the computer program.

The updated report contains state of the art information, advice and recommendations on the different principles, methods and guidelines which should be used and applied when conducting an economic evaluation of nuclear power plant bids. Also, an improved IAEA cost account system for nuclear power plants is listed in Annex I.

In parallel with the revision of the guidebook, an improved and updated software package for economic bid evaluation has been developed by Energoconsult Praha of the Czech Republic under contract to the IAEA. The new software, BIDEVAL-3, is based on advanced personal computer technology and is more flexible and user-friendly than the previous version. A description of the new software package is given in Annex II. The software package itself, including instructions for its use, can be found on the CD-ROM accompanying this report.

This report should be useful to the managers, engineers, economists and decision makers of electric utilities and governmental organizations in Member States, particularly in developing countries. The report should also be helpful to the suppliers of plant components and systems by providing a common framework for the preparation of bids.

The IAEA wishes to express its thanks to all those who were involved in reviewing the draft report and preparing the software, and to P.J. Meyer (Germany) for his chairmanship of these meetings. The Technical Officer at the IAEA responsible for the preparation of the updated report was Chuanwen Hu of the Division of Nuclear Power.

EDITORIAL NOTE

CONTENTS

1. INTRODUCTION

This report was developed by the IAEA to assist those Member States interested in using nuclear energy for power generation. The contents of the report constitute a fundamental part of the overall bid process. The entire bid process has been outlined in a series of IAEA publications, but these have not been updated to the same level as this report.

The introduction of a nuclear power plant (NPP) in a country, especially if it is the country's first nuclear project, is a major undertaking for all entities involved. The necessary planning work and co-ordination of the different fields of interest, from the point of view of governments, authorities, industries, universities and of the general public, must be done on a long term basis. This IAEA report may help support the work of the utility in the bidding process, especially in the economic bid evaluation. The different methods, aspects and parameters described should be regarded as a guide, noting that other approaches are feasible. The report's target criterion of lowest levelized discounted electricity generation costs (LDEGC) is a very useful and practical way of ranking bids. However, other criteria and methods of bid evaluation are feasible and may be applied to component based contracts with a limited scope of supply and services.

In view of the huge investment needed, and before any steps are taken towards introducing nuclear energy, the owner's country must be fully committed to a nuclear programme. A nuclear programme also requires a guarantee of long term financing, which implies the provision of local and foreign contributions. The national contribution should be government secured. Past experience indicates that changes can occur in the priorities of government, reflected in annual budgets and extensions to the construction period for the NPP. Such changes lead to high cost overruns, making the economic advantages of nuclear energy questionable. Therefore, it is important to consider not only the present economic situation, but also to provide an economic forecast for at least ten years. This forecast should include projected energy demand, development of the industry, market strategies, plant flexibility to grid requirements and economic parameters such as the inflation, interest and exchange rates in the supplier's and owner's countries.

The necessary staff for all of the various areas of a nuclear programme must be recruited and trained, a process which can take many years. The universities or technical high schools would have to play an important role in the education programme of those persons needed in the planning, licensing, engineering, operation and maintenance of the nuclear facilities.

Within the planning phase, the bid invitation specification (BIS) has to be prepared and sent out in order to receive bids for the scope of supply and services desired by the owner. The preparation of the BIS needs a great deal of experience and, probably at the stage of project implementation, the assistance of foreign consultants.

The evaluation of the bids received from the suppliers in response to the BIS is a huge task, taking many months or even years to complete. The evaluation process should lead to the selection of the best bidder and at least to the final decision on the partners constructing the NPP. The responsibility for the entire bidding process lies with the plant owner and has to be performed in the owner's organization. If assistance in special fields is necessary, experienced consultants and architect engineers (A/Es) may be integrated into the various working teams, structured as appropriate to support the overall project contract strategy. With respect to the balance of plant (BOP), the workload and the scope of responsibility of the owner is increasing as technology and regulation become more demanding.

For technology transfer, two requirements need to be satisfied: the owner needs a well established and experienced engineering capability, and the supplier must be ready and prepared to transfer the agreed technology in such a way as to support the project goals.

During the bid evaluation process, all aspects of the technical, financial and contractual approaches must be considered. Nowadays, political, socioeconomic and public acceptance aspects play a dominant role and lead to long term impact on the bid projects. Furthermore, the licensing of the various concepts has to be checked carefully.

Advanced reactor concepts are under development throughout the world. Some of these concepts are based mainly on the current generation of NPPs and, therefore, the degree of innovation is limited. Other concepts need more design work before marketing and may require the construction of a prototype plant. For these plants, licence certification or the defining of a reference may restrict the investor to a certain type of reactor. The safety related aspects have to be discussed and assessed in the technical bid evaluation and their impact on the economic bid evaluation is important.

In addition to the NPP itself, requirements for fuel fabrication facilities, intermediate storage facilities and final disposal of high level radioactive waste have to be planned carefully in a nuclear programme. Furthermore, access to a storage area for low and medium level radioactive waste must be provided. The respective licensing authorities have to be established and qualified, a process which is normally organized with foreign partners.

The main objectives of the economic bid evaluation are to establish the plant costs and to rank the available bids with the help of an economic figure of merit. This requires consideration of the following points:

- Results of the technical bid evaluation,
- Capital investment costs,
- Nuclear fuel cycle costs,
- Operation and maintenance (O&M) costs,

- Owner’s costs,
- Commercial and contractual terms and conditions,
- Financing proposals,
- Economic parameters,
- Domestic participation and technology transfer,
- Fringe benefits and spin-off effects,
- Political and socioeconomic aspects.

It should be clear to the user of this report that it is not possible to have a fully comprehensive manual for the treatment of all feasible types and combinations of contract approach. However, this report aims at providing the user with the following valuable information:

- General outline of the bid evaluation process;
- Detailed description of, and guidelines for, the economic bid evaluation process;
- Examples of different factors that should be taken into account in the economic bid evaluation;
- Description of methodologies and analytical tools applicable to the economic bid evaluation;
- Detailed description of the IAEA account system, which allows great flexibility in the technical and economic bid evaluation process;
- An economic bid evaluation computer program updated to the state of the art.

The structure of the IAEA account system incorporates a high degree of flexibility for the user. The various accounts offer an extension to additional levels of detail (of special interest for smaller contracts) or the choice of using only the top three to four digit levels of detail in the analysis. Additionally, the user may add new items not yet incorporated in the list of accounts.

2. OUTLINE OF THE COMPLETE BID EVALUATION PROCESS AND DESCRIPTION OF THE ECONOMIC BID EVALUATION

2.1. OUTLINE OF THE COMPLETE BID EVALUATION PROCESS

A flow diagram of the complete bid process for an NPP is presented in Fig. 1. The first step necessary to obtain offers from suppliers involves the preparation of the

BIS. In these specifications, the organization of the entire project should be explained in detail so that it is clear to the supplier(s) what the buyer wishes to purchase. The type of contract for project implementation — turnkey contract, split package contract or multiple package contract as discussed in Section 3 — must be clearly specified.

The BIS should be as complete as possible and should provide the bidders with all the data and information necessary for the preparation of the bids; this will also facilitate the subsequent evaluation and comparison of the tendered bids.

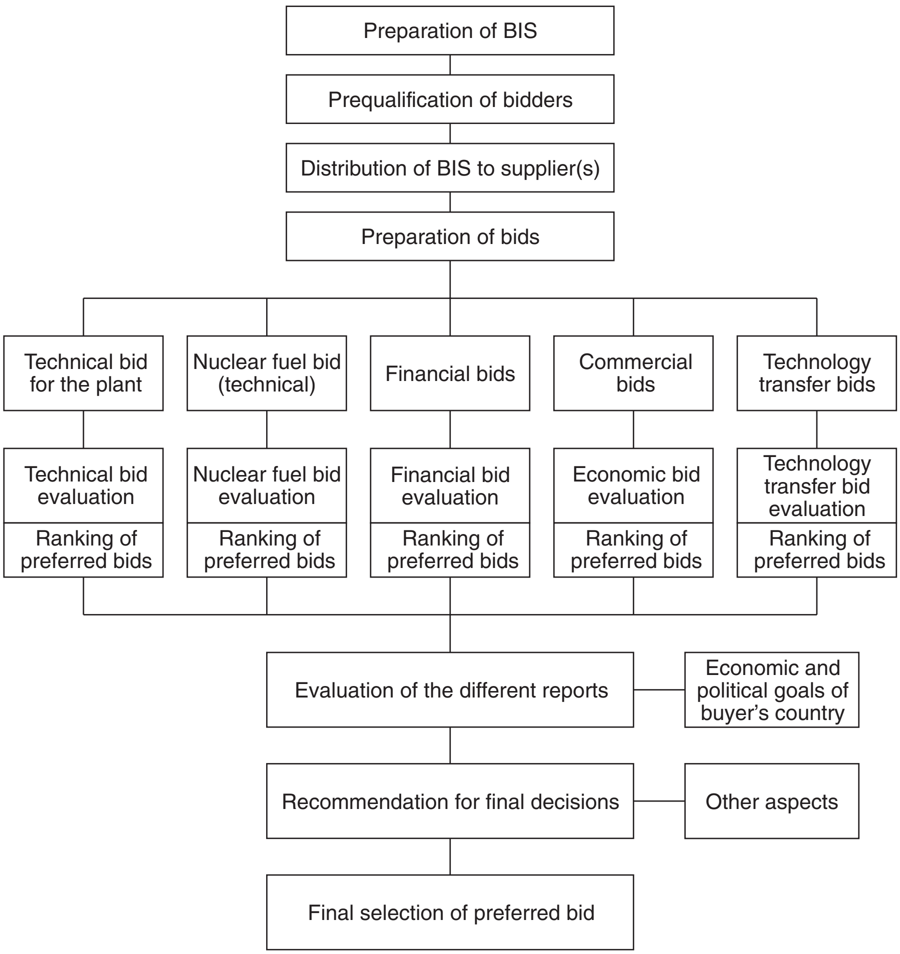

FIG. 1. Diagram of the complete bid process for an NPP.

A detailed description of the following items should be given:

- Subject of the BIS.
- Types and size ranges of reactor and its application (electricity production, process heat).
- Site description, including site data such as:
  - — Subsoil conditions.
  - — Cooling water supply, water supply for consumption in the plant during construction and operation.
  - — Seismic requirements, history of tectonic events.
  - — Auxiliary supplies (electricity, steam, hot water, compressed air, N_2, H_2, chemicals).
  - — Annual environmental conditions (temperature profile, incidence of hurricanes, snow, rainfall, humidity, etc.).
  - — Available infrastructure (roads, railways, harbours, transport equipment, cranes, hoists, etc.).
- Bidding conditions.
- Contract approach.
- Bid evaluation criteria.
- Administrative instructions.
- Electric grid requirements (frequency, total capacity, voltage available, grid expansion planning, mode of plant operation, base load or load follow-up).
- Technical requirements and criteria (national and international codes, standards, utility requirements, etc.), and regulations.
- National infrastructure.
- Safety philosophy and licensing requirements.
- Scope of supply and services desired, including definition of interfaces.
- Owner’s scope of supply and services.
- Fuel strategy, scope of supply and services.
- Project time and overall project schedule.
- Definition of references (see Section 2.3).
- Specification of technology transfer and national (local) participation.
- Commercial terms and conditions including outline of a contract (draft).
- Quality assurance programme at owner’s and bidders’ organizations.
- Financing, countertrade.
- Training of owner’s staff.
- Import requirements according to national legislation, considering the Nuclear Suppliers Group (NSG) guidelines or other international export regimes.
- Nuclear liability.
- Guarantees and warranties.

- Spare and wear parts, consumables for a specific period of operation (e.g. five years).
- Alternatives and options, deviations.
- In the case of the split package or multiple package contract approach, detailed and quantified data regarding work units for construction and erection of the NPP (concrete, reinforcement steel, steel structures, piping, etc.) should be requested in the BIS so that the owner may prepare cost estimates for those parts of the plant for which the owner is responsible.

2.1.1. Service contracts

In the nuclear market, service contracts are agreed upon for updates or renewals of equipment for the NPP that has been operating for several years. Special care must be taken in the preparation of a BIS for these types of contract. In particular, the technical and commercial conditions, desired scope of supply and services, interface data and documentation of the as built condition need special attention. The points mentioned need to be considered with respect to their interrelationships. Since various national and international organizations will be involved in these contracts, they must include a detailed description of the duties of, and interfaces among, the partners involved. These approaches will facilitate the bid evaluation that must be performed by the owner and/or A/E. An incomplete BIS does not constitute an effective document and creates difficulties in the comparison work.

2.1.2. Preparation of the BIS

For the preparation and organization of a BIS, the IAEA account system provides guidance to the owner in the specification of requirements for a given project. The comprehensive survey of accounts enables a more detailed breakdown of the scope of supply and services. The flexibility inherent in using this tool in an appropriate manner eases the vendors' bid preparation efforts and the owner's bid evaluation effort. Ambiguous or incomplete BIS documents force the supplier to make its own assumptions as to what is required, which often leads to higher prices (for further details see Section 4). The account system is qualified to enable specification of the following kinds of projects:

- Turnkey scope of supply;
- Split packages (nuclear island (NI), conventional island (CI) and BOP);
- Multiple package NPP scope (component basis);
- Update and refurbishment of current plants (components or limited special scope);

- Reconstitution, update, or modification of the plant design basis;
- Renovation of instrumentation and control (I&C) and reactor protection systems, including the related engineering work;
- Improvement of operational and safety systems;
- Exchange of major components (for a PWR, the exchange of steam generators, including increase of power output with renewal of the operating licence and associated licensing/engineering documents);
- Installation of advanced fuel assemblies enabling higher burnup and optimization of the use of uranium or mixed oxide fuel (MOX).

2.1.3. Qualification of suppliers

To ensure that prospective vendors have the necessary competence and experience to successfully complete a contract, they should be required to pass a pre-qualification process. The process should include demonstration of the vendor's financial capability and technical competence, and the provision of suitable references from entities in the supplier's country and from abroad. The pre-qualification is an excellent method of screening bidders and enables the owner to accept or reject bids. In the expanding service areas of maintenance, repair or especially the updating of current plants, the pre-qualification enables the owner to differentiate between international vendors that are qualified and vendors whose qualifications are limited.

For this purpose, a questionnaire to solicit the required data could be developed and sent to potential vendors. After the pre-qualification of the bidders is completed, the BIS and a request for bids should be distributed to the successful bidders. Depending on the scope requested in the BIS, an evaluation team could be established within the owner's organization to evaluate the incoming bids. The organization of the evaluation team and its work must be carefully planned.

2.1.4. Bidding procedures

The following bidding procedures are applied in international practice:

- Negotiated bids (the vendor has been selected in advance).
- Bids submitted as closed proposals (technical, economic and financial).
- Open bids, e.g.:
  —Public technical bid opening ceremony as the first step,
  —Presentation and opening of the commercial bids in the presence of the vendors in the second step,
  —Financing offered as a separate proposal or with the price bid.

In each case, however, the evaluation team has to prepare a technical evaluation report, including clarification of questions and answers from discussions between the bidders and the owner. If a bid has been prepared by a consortium, all vendors involved need to be qualified. Additionally, the offered scope of supply must be checked with regard to consistency with the scope and interface responsibilities among the offered bid packages.

2.1.5. Technical bid evaluation

The technical bid evaluation must include a review of the following items:

- Codes, standards, regulations, ordinances and utility requirements applied to the offered scope;
- Compliance with the technical BIS requirements, which could be equal to the utility requirements;
- Identification of deviations from the BIS;
- Technical alternatives;
- Technical references for the offered scope;
- Investigation report on the capability of local manufacturers (portion of national or imported supplies);
- Technology transfer as far as applicable.

2.1.6. Commercial and/or financial proposals

The analysis of the commercial proposal and/or the financing proposal must be performed by separate working groups. The results of the analysis, and especially the accompanying recommendations leading to the preferred bidder, have to be merged by a small team considering all of the requirements established in the BIS. The positive and negative aspects of each proposal need to be identified and translated into costs.

2.1.7. Draft contract

The assessment teams have to evaluate the draft contract, which is normally a part of the bid. The following main subjects must be considered:

- Objectives;
- Detailed scope of supply and services;
- Changes and options;
- Division of responsibility between owner and contractor;
- Financing arrangements, securities, taxation;

- Guarantees and warranties;
- Prices, price escalation formula, payment plan;
- Delivery times, broken down into individual items and engineering activities;
- Liability limits;
- Penalties;
- Nuclear liability in the recipient country;
- Guarantee of an export licence from supplier's country (end use certificate from the owner and import certificate from the government of the recipient country);
- Insurance;
- Confidentiality agreement;
- Arbitration;
- Termination of contract;
- Identification of the responsible project management team for the owner and contractor;
- Annexes.

The specific contract models should be reflected in the contract documents. If nuclear fuel is to be delivered, the various specialties in this field have to be placed under contract. The owner must decide early on in the planning stage how to contract for the uranium (natural or enriched) and the manufacture of the fuel elements, including their assembly. This decision is closely connected with alternatives for fuel (i.e. MOX insertion) and fuel management. Among the latter considerations are length of cycle, burnup, storage of spent fuel assemblies in the plant or in a central national intermediate storage facility outside the plant, reprocessing and final disposal. These items, which are briefly touched upon here, are further discussed in Section 4.5.

2.1.8. Technology transfer

Another area subject to assessment is the intended transfer of skills, methods and procedures to the owner's staff, as well as to local manufacturing industries, consultants, A/Es and licensing authorities (see Sections 4.6 and 8). In this field, the readiness and willingness of both sides to co-operate is of great importance. The planning and implementation of the nuclear programme have to be tightly co-ordinated within the country among all involved entities. Only a nuclear programme consisting of at least four to five units justifies the huge investment necessary, especially in the local manufacturing industry. The larger the nuclear programme being planned, the greater the amount that can be justified for investment and the greater the probable payback for investors in the local manufacturing industries. The development of competent authorities for licensing in the various fields (siting, environment, safety, radiological impact under normal and accident conditions,

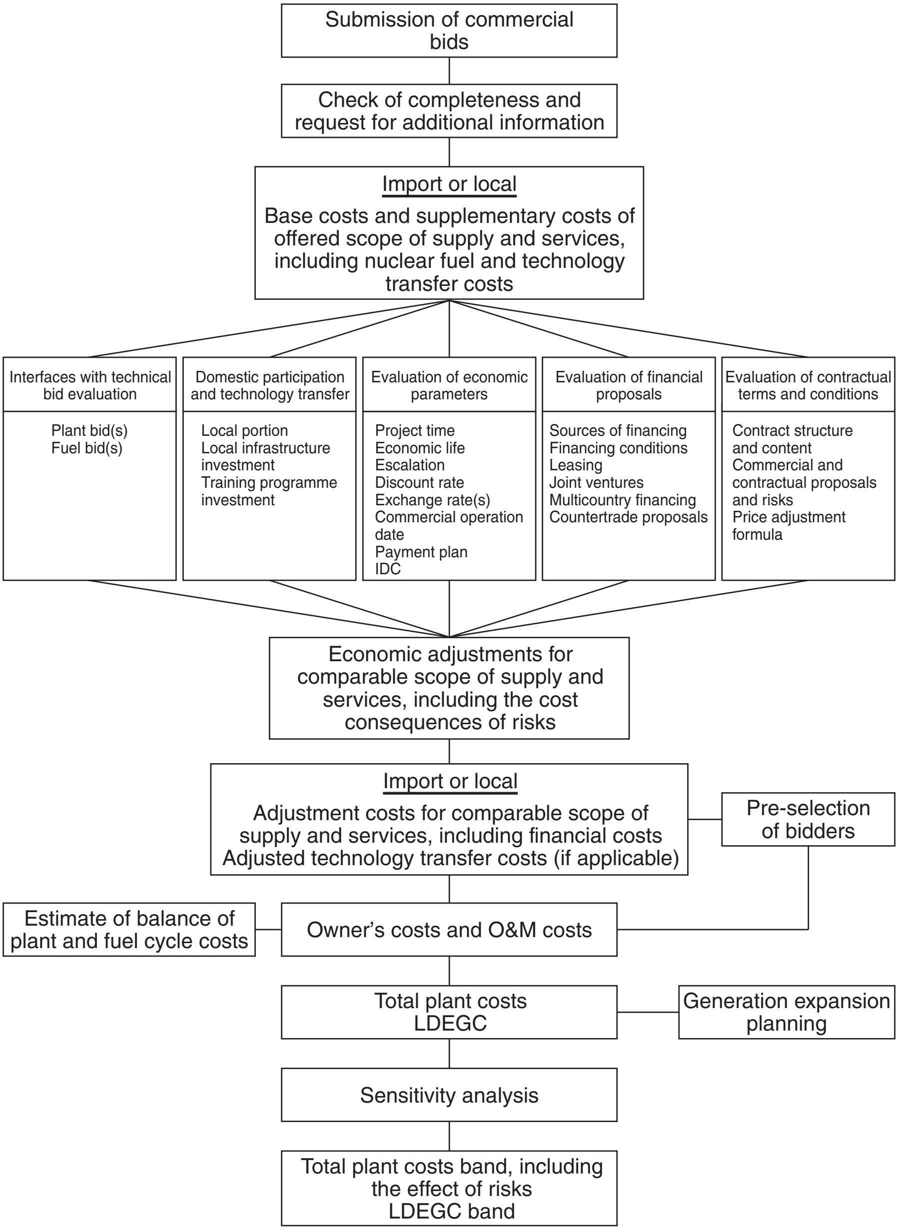

FIG. 2. Interface diagram of the economic bid evaluation process for a complete NPP.

lifetime control, etc.) is a major effort and needs early consideration. In many countries around the world, long term co-operation agreements between the authorities of the supplier's and applicant's countries constitute the basis for a prosperous joint effort.

The evaluation reports produced by the various assessment teams should be integrated by a supervisory group able to rank the bids in a certain order (see above). Technical, economic, financing and contractual aspects, as well as socioeconomic and political ones, have to be incorporated in the assessment. Furthermore, other essential issues have to be addressed, such as environmental impacts, public acceptance, energy independence and the balance of payments between countries.

Before recommendations can be made for a preferred bidder, contract negotiations with a reduced number of bidders are of great importance.

2.2. DETAILS OF THE ECONOMIC BID EVALUATION

This report mainly addresses the economic bid evaluation process, although there is a strong need to keep the entire bid process shown in Fig. 1 in mind, with the various details and results generated. An interface diagram of the economic bid evaluation process for an NPP is shown in Fig. 2.

The main activities to be performed by the various economic bid assessment teams are listed below (not necessarily in the order given):

- Checking the bids for completeness and compliance in accordance with the BIS (technical, economic, contractual, financing, technology transfer, fuel cycle);
- Identification of deviations and/or alternatives or options;
- Preparation of questionnaires to be answered by the bidders in addition to the content of the bids;
- Preparation and conduct of clarification meetings with the vendors;
- Assessment of correspondence between the offered scope and services and the price breakdown;
- Compliance control with associated interfaces as defined in the BIS, especially in the case of split package or multiple package approaches;
- Assessment of the technology transfer proposals in the various fields;
- Checking the plant performance guarantees for availability, load factor, power output, material properties and workmanship, margins in the design, heat rate, steam conditions, load follow capability, discharge burnup and fuel failure rate, and release of radioactivity;
- Assessment of commercial warranties such as project time, date of completion or start of commercial operation;

- Assessment of delivery times for nuclear steam supply systems (NSSS) or components for turnkey plants' contract approaches (engineering documents, technology documents, software and hardware);
- Adjustments of bid prices in the case of deviations or options selected by the owner instead of the scope specified in the BIS;
- Identification of uncertainties and risks (technical and commercial or financing);
- Checking the scope of wear and spare parts offered and evaluating the differences among bidders;
- Identification of contingencies, allowances and additional expected costs;
- Analysis of insurance costs for site, transport, erection and personnel;
- Checking the terms of payment for the various deliveries and services with regard to certain 'milestones';
- Analysis of the impact of the price adjustment formula;
- Analysis of the total price breakdown (the degree of price breakdown depends on the type of contract selected), which is divided into national and import portions;
- Analysis of the impact of different currencies offered by the vendors relative to the national currency of the owner's country (inflation and exchange rates);
- Possibility of reducing the amount of foreign funding;
- Optimization and risk assessment of local or foreign financing;
- Calculation of the total investment costs (vendor's portion and owner's costs, including costs for site and site infrastructure such as harbours, railways, roads, cranes, hoists, site village, workshops, fire-fighting installations, administration buildings, etc.);
- Evaluation of fuel bids;
- Assessment of various options at both the front end and back end of the nuclear fuel cycle;
- Assessment of financing proposals in connection with the terms of payment;
- Estimation of future rates (London Interbank Offered Rates (LIBOR)) for loans with variable interest rates;
- Selection of an appropriate real discount rate (should be specified in the BIS for the owner's country);
- Calculation of O&M costs;
- Calculation of fuel cycle costs;
- Calculation of owner's costs;
- Calculation of decommissioning costs;
- Performance of sensitivity analysis by variation of certain parameters (escalation indices for labour and material, interest rates, discount rates, currency exchange rates, load factors);
- Calculation of the plant costs and the LDEGC;

- Preparation of a summary evaluation report, including recommendation of the best bidder.

The plant costs (expressed in a reference monetary unit) include the total capital investment costs (TCIC), the nuclear fuel cycle costs, the O&M costs, the technology transfer costs and any other costs incurred during the economic life of the plant. Using the present worth analysis technique described in Section 5, the LDEGC (in reference monetary unit per kilowatt-hour) may be calculated in order to rank the offered bids.

In the tabular formats and/or in the computer program prepared for the evaluation, the base costs for the different scopes of supply and services must be entered according to the structure of the suggested IAEA system of accounts (see Section 4). The base costs, as well as the supplementary costs, have to be adjusted in order to make competing bids economically comparable. The economic adjustments are needed to put the different bids on an equal footing so that the offered scope of supply and services can be compared. The economic adjustments are assessed by considering the interfaces with the technical bid evaluation, taking into account the cost consequences of the differences or variations with respect to the BIS or to a selected reference bid. The reference bid is the bid considered to be the most complete as regards the technical scope of supply and services as well as the commercial and contractual aspects. The checklist provided in Annex I is particularly useful for assessing these economic adjustments, which need to be expressed in cost terms. The risk, in terms of costs, for different guarantees and warranties (for instance for the load factor or the availability factor, the net power output, the net heat rates and the fuel burnup), and the financing proposals, must be included at this stage. These are important steps in the evaluation process.

It is a basic principle of engineering economic analysis that the benefits obtained from, or the services rendered to, the electric grid should be equal for the various alternatives. If the net electric power output, the load following capability and other performance parameters differ substantially, then different generation reserve capacities will be required for the achievement of an equivalent reliability level of the electric power generation system. The values of some of the economic adjustments are functions of the electric power generation system in which the proposed alternatives are to be operated. Economic adjustments may also be required for a detailed study and evaluation of domestic participation, contractual terms and conditions, or financing proposals.

Once a comparable scope of supply and services is established among the bidders, it is possible to make a pre-selection of the bidders at this stage. The evaluation team can then concentrate on a few selected bids and proceed to the estimation of the costs for the BOP and the balance of the nuclear fuel cycle.

A small number of bidders (two or three) may be pre-selected in order to reduce the extent of the analysis and evaluation to be undertaken. The reliability of the pre-selection process depends on the type of contract (NI, NSSS together with nuclear fuel and/or CI). For each bidder rejected in this pre-selection process, a detailed report should be prepared which gives the reason for the negative decision.

Depending on the type of contract, the scope of the BOP varies. The BOP cost has to be estimated in order to obtain the cost figures for the complete plant. The economic risk involved in the estimation of the BOP for a turnkey project is less than for a project based on a split package contract or a multiple package contract. The BOP costs can be vastly different, particularly for different reactor designs.

Regarding domestic participation and technology transfer in the field of engineering, manufacturing, construction and quality assurance, the proposals have to be assessed on a case by case basis. In most cases, an industry-wide survey must be undertaken by the different suppliers in order to assess the present and the potential industrial capabilities of the owner’s country for the manufacture of NPP components. The results of this survey may form the basis of the proposals which will then be evaluated in the economic bid evaluation process.

Several of the economic parameters vary over the project period. To obtain a forecast of the influence of these parameters on the total plant costs, it is recommended that a sensitivity analysis be performed. In such an analysis, the variations of the economic parameters within a tolerance band will give a corresponding band of total plant costs. For budget planning purposes and for project financing, it is necessary to obtain this information in advance. It must be clearly understood that there is always a risk that cost increases may occur over the project period.

An economic risk assessment may also be performed. In this case, a probability distribution for each factor and/or input variable is required. The larger the scope of the BOP to be estimated, the greater the risk. For bid comparison, these risks have to be carefully investigated. After completion of the risk analysis, the adjusted costs can be converted to one currency, at a reference date, in order to obtain the total plant costs. Because of the uncertainty in some of the parameters, a probability distribution of the total plant costs may be obtained.

It must be realized that not all of the differences found in the various bids for the scope of supply and services, the contractual parameters, the level of domestic participation and technology transfer, and the financial conditions, can be expressed in cost figures. Therefore, a detailed qualitative analysis and comparison are needed to account for differences in contractual items and clauses. These qualitative aspects also play an important role in ranking the different bids.

To obtain the total plant costs, an estimate of the fuel cycle costs, O&M costs, owner’s costs, decommissioning costs and technology transfer costs, as appropriate, should be made and added to the TCIC. In addition, to obtain the LDEGC, the expected energy generated by the plant or generating unit must be assessed. This can be done either by estimating the load factors or by simulating the operation of the generating unit by means of a suitable generation expansion planning program. In practice, this will be a marginal effort since utility planners routinely use such computer programs for electric power generation system expansion planning. The simulation of plant operation over the next 20 or 30 years introduces large uncertainties, especially in the estimation of economic parameters and electrical system load growth. However, the description of this effort is beyond the scope of this publication.

The report on the economic bid evaluation should present the results obtained, identify open points for contract negotiations and suggest a ranking of the different bids on the basis of the factors mentioned.

This short description of the bid evaluation process provides a general guideline. The economic bid evaluation process is described in more detail in the following sections.

2.3. REFERENCES

In almost every BIS, a reference plant which has been in commercial operation for at least two years is requested from the bidders. Considering the actual planning and construction time of approximately 10 years, the specified reference plant may represent a 10–15 year old technology. However, as the marketing of NPP technology advances, so the preconditions for nominating a reference plant need to be adapted to the introduction of the new generation of advanced reactors that have little or no commercial operating experience.

In the suppliers' countries, the developmental status of the advanced plants that may be offered varies considerably and may not include operating experience. When a reference plant is requested in the BIS, however, the design requirements often ask for the application of proven design and components in order to take advantage of extensive commercial operating experience. Consequently, a detailed specification of the reference plant that states what the owner needs to fulfil regarding its goals and objectives and what it wants to receive with the bids must be included in the BIS. The following examples may be used for guidance.

2.3.1. Licensing

The entire licensing process in many countries has been split into a number of steps, each of which require a tremendous amount of documentation. This has particularly been the case for new rules and regulations promulgated by the authorities. Because of the seemingly endless increase in the engineering work necessary to get a construction permit, costs have increased and schedules lengthened. To reduce costs and construction time, considerable effort should be directed towards streamlining the licensing process by developing methods to reduce the great amount of required documentation.

For the economic bid evaluation, a reference should be specified in the BIS to the licensing procedure applied in the owner's country. If there is no experience, or only limited experience in licensing available in the owner's country, the procedure practised in the vendor's country may be selected as the reference. The potential impact of the licensing process with regard to project time, construction periods and cost overruns can be of great importance.

The basic document needed for licence application is the preliminary safety analysis report. In addition, severe accidents, termed 'beyond design basis accidents', have to be analysed.

Validation of the entire concept, particularly the safety concept, which includes accident prevention and mitigation measures, accident management, and identification of qualified systems and components, must be made for reference purposes. Deviations from the standardized design as a result of site conditions should be explained separately.

2.3.2. Reliability

The reference design, as well as the offered concept, should be free of generic problems, which could adversely affect reliability.

The validation of mechanical, electrical, and I&C equipment offered in the bid must be certified and referenced in technical terms. The validation must also be certified with respect to the operating experience of an NPP operating in the bidder's country. If new technology is to be incorporated in the bid, then the related qualification process should be incorporated in the bid documentation. It is desirable for the offered technology to have been in operation for at least two years in order to demonstrate its reliability. This requirement, however, only allows for existing technology to be employed. If new technology is offered and desired, demonstration of reliability should be based on an appropriate combination of analysis, testing and/or in-kind experience.

For the layout and design of an NPP, the following aspects may be selected for references:

- Layout of the site independent buildings.
- Design parameters of the structures to take account of:
  - External impacts, e.g. aeroplane crash, gas cloud explosion, earthquakes and other natural disasters, and subsoil conditions, as applicable;

  — Impacts originating inside the NPP, in accordance with the scope of hypothetical accidents;
  — Radiological release rates, personnel exposure.
- Qualified materials for components.
- Performance data.
- Maintainability and maintenance experience.
- Design life of components.
- Failure rates for components and fuel assemblies.
- Design margins.
- Codes and standards applied.
- Operating experience.

2.3.3. Constructional viability

The reference design should be checked with regard to its constructional viability. Problems identified should be resolved in the final design to prevent them from impacting the construction process.

2.3.4. Scope of supply and services

A reference for the scope of supply and services that is selected from a single or multiunit NPP always leads to conflict. In this regard, consideration of the types of contract that are discussed in Section 3 is essential for the reference which has to be defined.

A turnkey contract incorporates a completeness clause. The selection of a reference for a turnkey plant depends on the requirements of the proposed reference plant operator and how closely the owner of the new plant is willing to adopt the conditions of the reference plant. The completeness clause is useless unless all of the details subject to the reference are specified. If the owner requests related references in the bid component list, the references should be specifically identified in a separate column.

In the split package proposal, comparable systems could be used as reference technology, as far as applicable.

The multiple package approach is one of the most difficult subjects for references, especially if the components included are of different origin (national supply). For this contract approach, it is recommended that the aspects outlined in Section 2.3.2 be considered for reference.

2.3.5. Conclusions

The above examples illustrate the difficulties and problems that are related to references, particularly when considering that the last plant order in the suppliers' countries would have taken place many years previously. The technology of such a plant should not be taken as a reference without question, because the ‘state of the art’ of that technology could be outdated. In the meantime, a new generation of NPPs, the advanced NPP, has been designed and developed and may be offered in response to the BIS. Although the availability of references is therefore very limited, some kind of reference may be feasible under given circumstances.

3. CONTRACT APPROACHES

3.1. INTRODUCTION

The scope of the economic bid evaluation can vary significantly, depending on the contractual approach selected for the project. Also, the amount of work for the plant owner depends on the scope and the degree of detail and accuracy required. The economic bid evaluation will become progressively more comprehensive and complex, the more the plant owner desires to be involved in the design, construction and/or operation.

To date, basically three main types of contractual approach have been applied to NPPs. Additionally, one other type, having two variations, has been applied to a few conventional power plants in recent years. The four types are:

(a) *Turnkey contract.* A single contractor or consortium of contractors takes overall responsibility for completing all parts and all phases of the project design and construction.

(b) *Split package contract.* The overall responsibility for the design and construction of the project is divided among a relatively small number of contractors, each contractor being separately in charge of a large section of the work. The involvement of an A/E may be required.

(c) *Multiple package contract.* The plant owner, possibly with the assistance of an A/E and/or consultants, assumes overall responsibility for managing the design and construction project. A large number of contracts are issued to various contractors which carry out parts of the project.

In approaches a, b and c, a complete power plant, ready for operation, is delivered to the owner at the end of construction and acceptance/startup testing.

(d) *Build, own and operate (BOO) or build, own, operate and transfer (BOOT).* The plant ownership deviates from contract approaches a, b and c because a foreign investor has to plan, construct, operate and provide the financing for the NPP. This investor must also carry the risk over the entire plant life, or part of it. BOO and BOOT are contract approaches similar to the turnkey contract, except that there is a major difference in the ownership of the plant over all (BOO) or a part (BOOT) of the plant's life.

In the case of a turnkey contract (type a), the contracting organization may consist of an individual contractor, also called a general contractor, or a consortium of contractors operating in a joint venture. The main contractor is fully responsible to the plant owner for plant quality and function, plant completion date and plant investment costs (in many cases this responsibility is shared with the plant owner). Also, the consortium of contractors may be responsible jointly or separately for these three items. The contractor has to cover by its guarantee its own delivery and services, as well as the deliveries and services of its subcontractors, foreign and local. The owner must provide the necessary site information and infrastructure and must prepare for the training of staff during plant construction, and for operation and maintenance after startup. For a new reactor concept, or reactors containing major innovations in design and layout (i.e. the advanced reactors currently being developed), it is recommended that a turnkey type contract be utilized to minimize the various risks and the number of interfaces.

In the case of a split package contract (type b) (i.e. NI, CI and BOP), or a multiple package contract (type c), the owner organization may have its own A/E group, an outside A/E, or both for co-ordination of the interfaces. In these approaches, the plant owner has the same responsibilities relative to site, infrastructure and training as in a turnkey contract.

In the BOO or BOOT contract (type d) approach, the contractor or consortium retains ownership of the new plant after commercial startup. The contractor is responsible for operating the plant and selling the electricity generated to the local utility at conditions agreed upon in a contract. The contractor's additional responsibilities are maintenance, repair and refuelling. The methods for the treatment and disposal of the radioactive wastes (low, medium and highly active) have to be agreed upon with the local utility and the government. This aspect is especially important in the BOO approach. In the BOOT case, the various agreements and responsibilities have to be assumed after transfer of ownership takes place. After transfer of ownership, the utility's obligations include the handling and storage of the various radioactive wastes.

The foreign investor must be prepared to construct an NPP in a foreign country utilizing its own capital. Additionally, the potential risk of incurring problems with the following needs to be carefully assessed:

- Site and construction licences,
- Limited support by local industries,

- Limited access to the electric grid,
- Probability of no clear ownership of the electric grid,
- Lack of guarantees for delivery of certain annual MW(e) for a price covering the costs.

Furthermore, the political, environmental and nuclear liability risks have to be covered and should form the basis of a contract. In the case of nuclear liability, only the government would have sufficient resources to provide indemnification for such liability. To what extent the government is willing and able to cover this risk remains an open question. Other open questions concern which of the contract parties will take the lead responsibility for the financial risks during plant construction and operation and how the risk will be shared among the parties involved. The probability is rather low that a single entity would be able to accept the high risks related to a BOO or BOOT contract approach for construction of an NPP.

It should be noted that neither the BOO nor BOOT type of contract has yet been utilized for NPP construction anywhere in the world. The reason for this is that there are no satisfactory solutions at present for acceptance of the high risks outlined briefly above. A survey of the problems that need to be considered for the BOO or BOOT approach is included in Section 3.2.

This contract model was incorporated in the report for the sake of completeness and for identification of the problems which have to be resolved among the parties involved. The report does not give further consideration to this model in the discussions of the economic bid evaluation process.

One of the key decisions which has to be made by the plant owner before the preparation of the BIS is the choice of contractual approach for acquisition of an NPP. Decisions must also be made regarding how the project management, particularly the construction and commissioning management, and plant operation are to be organized. Additional decisions need to be made as to how the responsibilities are to be shared, not only for the project work but also to some extent for the final quality and reliability of the plant. It should be kept in mind that the selection of the type of contract will fundamentally affect the key aspects of project implementation. The desired contractual approach must be specified in the BIS.

The kind of contractual approach to be adopted for a particular project can only be determined once all the salient factors have been carefully evaluated. The balance of advantages and disadvantages for a given project can best be judged if a project approach study is carried out. The project approach study can be accomplished in parallel with the studies of domestic participation. The main factors to be evaluated are the following:

- The national nuclear programme;
- Domestic participation policy and plans for the development of local engineering and industrial capabilities;

- Availability of qualified project management personnel, and co-ordinating and engineering personnel;
- Existing engineering and industrial infrastructures in the owner's country;
- Capability to build local supporting infrastructure, including licensing authority, nuclear fuel handling, O&M, radioactive waste handling/storage and decommissioning;
- Availability of technical assistance from an owner or owners that are operating the plant type(s) of interest;
- Ability to set and rigorously maintain a BIS preparation and bid evaluation schedule;
- Ability to pre-qualify suppliers with respect to their particular experience with different contract approaches and with regard to their particular management and engineering experience;
- Experience of the plant owner with similar projects;
- Plant design criteria and engineering features;
- Standardization and the degree of demonstrable technology for the proposed reactor type;
- The ability to validate potential reactor types through past design and operating experience;
- Quality of collaboration with nuclear consulting engineers and/or the A/E group;
- Government and industrial relationships (political, commercial) with the supplier's country;
- Economic considerations;
- Ability to optimize the relationship and benefits between technology transfer and project procurement strategy;
- Financing prospects;
- Warranty and liability considerations, including nuclear liability;
- Consideration of competition.

For each project, great effort should be made to select and develop the most suitable project approach strategy. For the first nuclear project, all factors have to be evaluated in depth. For subsequent units, the evaluation may be limited to those factors which have changed since the first unit was committed.

3.2. INFLUENCE OF THE CONTRACTUAL APPROACH ON THE ECONOMIC BID EVALUATION

From the economic point of view, it is necessary for the plant owner to know the particular advantages and/or disadvantages connected with each type of contract, since this has a direct or indirect impact on the costs and cost structures. The advantages and disadvantages are clearly project specific and/or country specific and may not apply in all cases. Some particular aspects of the different types of contractual approach which may have cost consequences are summarized as follows:

Advantages to the owner	Disadvantages to the owner
(a) Turnkey contract:	
Better possibilities through contractual arrangements for the highest degree of integrity and homogeneity in the scope of supply and services	Limited project control
Technical guarantees and commercial warranties covering the plant as a whole, i.e. net power output, availability, heat consumption, speed of power change, fuel burnup, delivery time, etc.	Limited hands-on experience
Reduced interface management control and engineering costs	
Minimum risk of cost impact for a state of the art reactor	
Reduced risk of overall schedule delays	
Minimum co-ordination effort for cost control	
Utilization of standardized, proven techniques for the whole plant	
Greatest opportunity to secure attractive, large, foreign financing package	
Quicker compilation of detailed project documents	

Advantages to the owner	Disadvantages to the owner
Consistent documentation	
Maximum assistance by the supplier in meeting regulatory requirements	
(b) Split package contract (NI approach):	
Moderate risk of cost impact for a state of the art reactor	Increased responsibility as a result of compatibility problems between systems
Moderate risk of overall schedule delays	Increased interface problems
Opportunity to purchase from two or more suppliers and/or countries, which facilitates securing large amounts of foreign financing	Greater responsibility owing to increased management control
100% control of the selected design and construction, and project management	Licensing risks
Construction with foreign staff possible with high degree of local participation	Risk of tremendous cost overruns and repayments
Use of own capabilities	
Establishment of consortia or joint venture	
Increased project control	
Moderate opportunity for hands-on experience	
(c) Multiple package contract (component approach):	
Opportunity to tailor the plant	Maximum risk for a state of the art reactor plant and its components and systems

Advantages to the owner	Disadvantages to the owner
Maximum ‘hands-on’ experience	Maximum responsibility as a result of compatibility problems between systems and components, interface management control, quality assurance/quality control verification, final plant performance and project schedule
Involvement of different vendors	Reliance on owner’s A/E (which does not take risks of cost overruns)
Procurement by the owner	Maximum co-ordination effort for cost control, financing arrangements, site management, control during construction and commissioning
	Licensing risks
	Risk of delays and cost overruns
	Owner needs large engineering staff

(d) BOO, BOOT

The main problems associated with the BOO/BOOT contract approach are those which the suppliers face when contracting to build an NPP in a foreign country. Because of the characteristics of BOO/BOOT, the owner and supplier may be the same entity. If a BOO/BOOT BIS is considered necessary, however, provisions may be included to protect the responsible organizations from any adverse effects that might occur. In order to devise such protection, qualified and experienced advisers should be included in the evaluation team. The complexity of this contractual approach, including potential risks in various fields, is exemplified in the survey of problems listed below. The description of BOO/BOOT has been discussed in some detail in this report in order to enable the parties considering a BOO/BOOT contract approach to be able to check these details with sufficient care.

Problems related to the BOO/BOOT contract approach are listed as follows:

- Nuclear liability.
- Financial risks.

- Risk of licensing in foreign countries.
- Application of local rules, codes, etc.
- Large investment from own resources or through national/international financing.
- Buildup of operating and maintenance staff.
- Construction of the plant on a foreign site.
- No free decision on plant size.
- Risk of political instability.
- Risk of expropriation.
- No free access to the grid, but responsibility for frequency control.
- Tariff structure may be government controlled.
- High expenditures for a single plant.
- Risk related to conforming with local requirements.
- Buildup of local infrastructure and local industry capabilities.
- Recruitment of local staff, with related high investments in education and training.
- Difficulties with public acceptance.
- Precautions for the nuclear fuel cycle.
- Responsibility for radioactive waste treatment and storage of highly radioactive waste.

The turnkey and the BOO/BOOT approaches are least likely to incur cost overruns. The split package and the multiple package approaches can be more expensive for the first nuclear plant, but they may have the advantage of providing better development of domestic nuclear capabilities for future plants.

It is often assumed that the advantages offered by one contractual approach can not be obtained without sacrificing the advantages promised by another approach, but this need not be the case. There have been turnkey contracts with a high degree of domestic participation and adequate owner influence on design decisions. On the other hand, there have been multiple package contracts with schedule and costs within the original targets. For a developing country with limited staffing resources, the best way to solve co-ordination problems among various contractors may be to give the lead responsibility for overall project management to a single supplier. This supplier should be one which has successfully demonstrated its technical and project management capabilities in plant construction and commissioning away from its home base and preferably in a developing country.

In the case of a split package approach, coverage of the warranties needs special attention. This type of contract does not provide the overall warranties offered by a turnkey contract, but only limited warranties for the separate packages. The plant owner or its A/E should request from the main supplier(s) detailed interface instructions for the system, subsystem or component to be designed and built. For the plant owner, interface problems may represent the risk of delays and extra costs.

Similarly, in the case of a multiple package contract, the A/E group must provide the interface co-ordination for the plant owner. Typically, warranties will be given for individual component or package scopes, typically only for materials and workmanship, but not for system performance.

If a BIS allows various approaches, then the bid evaluation process will need to consider the economics of internal versus external O&M costs, energy pricing and radioactive waste costs of each approach. If a BIS allows tenders for advanced reactor types, then the risk associated with unproven technologies will need to be weighed against predicted cost reductions and increased capacity factors.

Figure 3 provides a schematic representation of the three basic contractual approaches. Civil works may form a separate package in the split package type of contract. Note that in the case of a multiple package contract, the electrical BOP, the mechanical BOP, the balance of nuclear island (BONI) and the balance of conventional island (BOCI) may be split into many packages.

For all three basic types of contract there is an owner's scope of supply. This scope of supply comprises the essential tasks and activities that must be performed by the owner and for which responsibility can not readily be delegated to others. The plant owner has ultimate responsibility for the choice of the plant and for its safe and efficient operation, subject to the influence, policies and supervision of the government.

3.3. COST IMPACTS FROM CONTRACT APPROACHES

As outlined above, different contract approaches are being or may be utilized for the construction of NPPs. The more the scope of supplies and services is subdivided among various organizations, the greater the number of interfaces and strategic functions. The additional costs for interface control and project management have to be carefully estimated. Also, should the project duration be extended, the capital costs will increase and the contract arrangements will have to be adapted to the new project conditions. The various contractual items have to be checked with respect to their cost consequences and their overall economic impact. The related cost information will need to be integrated into the economic bid evaluation.

Usually, a draft contract, whose content is similar to that outlined above, is included as a part of the BIS documentation. The draft should be carefully checked for cost implications, either on a qualitative or a quantitative basis. The inherent costs identified in this checking procedure need to be incorporated into the economic bid evaluation in order to understand the impact of the contract terms in the results of the evaluation.

There is also a strong need to assess the risks associated with the different contract approaches and to analyse their economic consequences. The most difficult

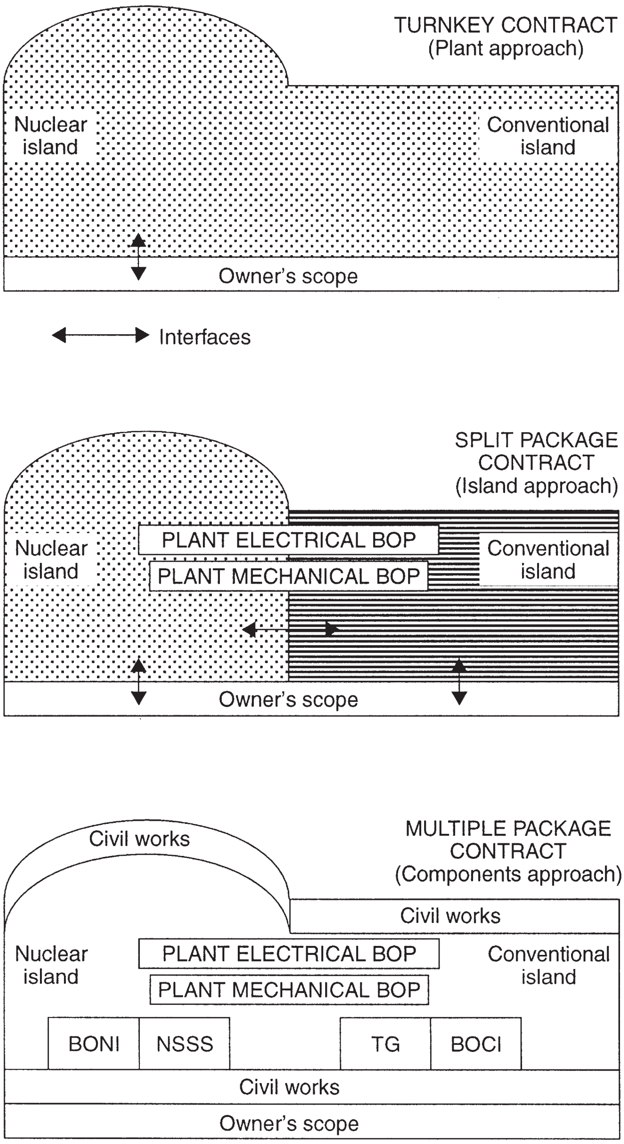

FIG. 3. The three types of contract. NSSS: nuclear steam supply system; BOCI: balance of conventional island; BONI: balance of nuclear island; BOP: balance of plant; TG: turbine generator.

TABLE I. OUTLINE CONTRACT FOR TURNKEY NPP (EXAMPLE)

1. Definitions

2. Basis for the plant contract
   - 2.1. General
   - 2.2. Applicable laws, regulations, codes, ordinances and requirements
   - 2.3. Contract documents, including correspondence and language
   - 2.4. Fuel contract arrangements, including raw material and supplies
   - 2.5. Effective date of the work

3. Scope of supply and services
   - 3.1. General
   - 3.2. Scope of supply and services of the supplier
   - 3.3. Scope of supply and services of the purchaser
   - 3.4. Changes in the scope of work
   - 3.5. Spare and wear parts

4. Documents and documentation
   - 4.1. General
   - 4.2. Technical documentation: Drawings, specifications, calculations, special reports, etc.
   - 4.3. Interface documents
   - 4.4. Licensing documents
   - 4.5. Technical documents for acceptance
   - 4.6. Non-technical documents, including commercial documents, such as invoices, transport documents, tax and customs documents, etc.
   - 4.7. Construction, erection and operation procedures
   - 4.8. Commissioning of the plant
   - 4.9. Trial test run, including acceptance test
   - 4.10. Operation and maintenance manuals

5. Contract agreements
   - 5.1. Proprietary information
   - 5.2. Assignment of work and subcontracting
   - 5.3. Quality assurance and quality control
   - 5.4. Rights for inspection at the facilities of various subcontractors
   - 5.5. Modification and changes
   - 5.6. Patents and royalties

6. Risks, liabilities and title
   - 6.1. Risk of loss or damage
   - 6.2. Non-nuclear liability
   - 6.3. Nuclear liability
   - 6.4. General liability
   - 6.5. Transfer of title

TABLE I. (cont.)

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7. Insurance
   7.1. General
   7.2. Various types of insurance for the entire project

8. Licences
   8.1. Erection, commissioning and operation licences
   8.2. Import–export licences
   8.3. Special permits requested by the owner's country

9. Training of operating and maintenance personnel
   9.1. On the job training
   9.2. Assignment of personnel
   9.3. Simulator training
   9.4. Retraining

10. Plant contract schedules
    10.1. General plant construction schedule
    10.2. Effective date and start of construction
    10.3. Consequences of delays

11. Technical warranties and guarantees (warranty periods)
    11.1. Design, materials and workmanship guarantees
    11.2. Plant performance guarantee
    11.3. Rectification of defects and failures
    11.4. Special component guarantees
    11.5. Availability guarantees
    11.6. Penalties and bonuses

12. Contractual price and financing
    12.1. Base price
    12.2. Price escalation and adjustments
    12.3. Financing: Local and foreign

13. Terms of payment

14. Force majeur

15. Termination of contract

16. Applicable law

17. Jurisdiction: Disputes and arbitration

TABLE I. (cont.)

18.	Organizational matters
	18.1. Representatives
	18.2. Addresses
	18.3. Shipment and transportation
	18.4. Local arrangements and precautions
19.	Service contract

task is to translate these risk parameters into costs, because many of the items listed in Table I have different impacts on different types of contract. If no cost figures can be reasonably generated from the risk evaluation, a qualitative description and ranking of the risk should be prepared. In general, the more the contract responsibilities are subdivided, the higher the risk would be to the purchaser of the supplies and services.

This short description of contract related cost effects highlights the importance of carefully considering and defining the interfaces and responsibilities among the various partners called for in the BIS. The various cost impact items outlined in Table I can not be discussed in further detail because of their commercial implications. The information gained from their analysis should be used to select the most favourable type of contract for the circumstances and to provide the basis for optimizing the type selected.

4. BASIS FOR THE ECONOMIC BID EVALUATION

4.1. INTRODUCTION

The economic bid evaluation is based on the following data and information:

- Cost information tabulated in accordance with the IAEA account system, such as:
  - — NPP investment costs, or for a reduced scope of supply (single components or systems) as specifically addressed in the BIS;
  - — Nuclear fuel cycle costs;
  - — O&M costs.
- Result of the technical bid evaluation, including cost estimates to account for technical differences.
- Commercial and contractual terms and conditions.

- Economic parameters.
- Financing proposals (local and foreign portion).
- Domestic participation and technology transfer (the local investment costs for industry, education of staff, infrastructure, authorities, research and development, and others may be calculated separately).
- Owner's costs.

The IAEA account system can be applied for determination of the completeness of bids, identification of deviations in the scope of supply and services, and estimation of the BOP costs.

From a practical standpoint, and on the basis of current practice, it must be understood that the level and completeness of cost detail available for inclusion in the IAEA account system at any point in the bid evaluation process will depend on the type of contract being requested and the stage of contract negotiation. For example, much more data at a detailed level will be available for a multiple package contract bid evaluation than for a turnkey contract bid evaluation. Likewise, more detail will become available at the 'question and answer' phase of the bid evaluation process than will be available for the initial bid.

4.2. IAEA ACCOUNT SYSTEM

The IAEA has developed a comprehensive account system capable of addressing a spectrum of capital costs, fuel cycle costs and O&M costs, from a complete NPP down to individual systems or components. Since the account system has a high degree of flexibility, it can be used with all types of reactor, single or dual purpose power plants, and various contract approaches.

It is recommended that reference be made to the account system included in the BIS in order to facilitate completeness of control and the total bid evaluation process.

4.2.1. NPP capital investment costs account system

The investment costs for a complete NPP, or parts of it, include the costs of engineering, construction, commissioning and the trial test run up to commercial operation. The 'base costs' include costs associated with the equipment, structures, installation and materials (direct costs), as well as the engineering, construction and management services (indirect costs). In addition to the base costs there are also supplementary costs, financial costs and owner's costs. Supplementary costs include spare parts, contingencies and insurance. Financial costs include escalation, interest during construction (IDC) and fees. Owner's costs include the owner's capital investment and services costs, escalation and related financing costs.

The ‘fore costs’ or ‘overnight costs’ consist of the base costs, the supplementary costs and the owner’s capital investment and service costs.

The TCIC are the costs of building the NPP and bringing it to commercial operation. The breakdown is shown as follows:

$$\text{Base costs} = \left\{ \begin{array}{c} \text{Direct costs (Account nos 21–29)} \\ + \\ \text{Indirect costs (Account nos 30–41)} \end{array} \right\}$$

$$\begin{array}{l}\text{Fore costs} \\ \text{(overnight costs)}\end{array} = \text{Base costs} + \left\{ \begin{array}{c} \text{Supplementary costs (Account nos 50–54)} \\ + \\ \text{Owner's capital investment and services} \\ \text{costs (Account no. 70)} \end{array} \right\}$$

$$\begin{array}{l}\text{Total capital} \\ \text{investment costs}\end{array} = \text{Fore costs} + \left\{ \begin{array}{c} \text{Escalation costs (Account nos 60, 71)} \\ + \\ \text{Interest during construction and fees} \\ \text{(Account nos 61, 62, 72)} \end{array} \right\}$$

The NPP TCIC account system is a numerical system designed to provide cost information for any component of a particular project, from design, layout and procurement of equipment, up to the final installation. The IAEA account system is primarily a system of cost accounts and is based on a physical subdivision of the project. However, it may also be convenient to use it for other purposes, such as filing, drawing and document control, and numbering and coding of equipment. The advantages are that this system eliminates the need to develop separate systems for each purpose, so that only one system needs to be learned, and provides a common language for the whole project, so that various phases of the work can be readily related.

In the NPP TCIC account system, base costs are allocated to accounts 21–41, supplementary costs to accounts 50–54, financial costs to accounts 60–62, and owner’s costs to accounts 70–72, as shown in Table II.

Account 21 includes all of the costs for buildings and structures, such as the bulk material and the associated engineering and documentation for construction work at the site. It is important to note that accounts 22–27 include costs of equipment manufacture, materials for components and systems, and the engineering and documentation associated with the manufacturing process in the factory.

Pre-installation assembly/site fabrication costs of some of the main components may be entered under accounts 22 and 23, where appropriate. General site

TABLE II. STRUCTURE OF THE IAEA NPP TCIC ACCOUNT SYSTEM

Account number	Account title
Base costs:	
21	Buildings and structures at the plant site
22	Reactor plant equipment
23	Turbine generator plant equipment
24	Electrical equipment and I&C plant equipment
25	Water intake and heat rejection
26	Miscellaneous plant equipment
27	Special materials
28	Simulators
30	Engineering, design and layout services provided by the supplier(s) and/or the A/E at the home office(s)
31	Project management services provided by the supplier(s) and/or the A/E at the home office(s)
32	Engineering, design and layout services provided by the supplier(s) and/or the A/E at the plant site
33	Project management services provided by the supplier(s) and/or the A/E at the plant site
34	Construction site supervision provided by the supplier(s) and/or the A/E
35	Construction labour provided by the supplier(s) and/or the A/E or construction companies at the plant site
36	Commissioning services provided by the supplier(s) and/or the A/E at the plant site
37	Trial test run services provided by the supplier(s) and/or the A/E
38	Construction facilities, tools and materials at the plant site
39	Commissioning materials, consumables, tools and equipment at the plant site
40	Staff training, technology transfer and other services
41	Housing facilities and related infrastructure

TABLE II. (cont.)

Account number	Account title
Supplementary costs:	
50	Transportation and transportation insurance
51	Spare parts
52	Contingencies
53	Insurance
54	Decommissioning costs, if not included in O&M costs (account 870)
Financial costs (including accounts 21–54):	
60	Escalation costs
61	IDC
62	Fees
Owner's costs (excluding accounts 21–62):	
70	Owner's capital investment and services costs
71	Escalation of owner's costs
72	Financing of owner's costs

construction, installation labour and field supervision costs are included in accounts 34–39. Engineering and design work performed by the supplier and/or the A/E at the home office(s) has to be calculated under account 30.

Table II presents an outline of the IAEA account system used in preparing a summary of the TCIC. It should be noted that the investment costs for fuel are not included. Heavy water costs may be included (if they are not included in the fuel cycle costs account system). Whether these items are included or not, either in the TCIC or in the fuel costs, has no effect on the overall results of the evaluation of the LDEGC. The sum of the base costs, the supplementary costs, the financial costs and the owner's costs gives the TCIC.

4.2.2. Nuclear fuel cycle costs account system

The nuclear fuel cycle costs include the costs of uranium supply, conversion and enrichment; fuel fabrication; transport; spent fuel intermediate storage and final disposal of the spent fuel (for the direct disposal option). For the reprocessing option, the costs also include those for chemical reprocessing associated with waste management, along with storage and final disposal of high level radioactive waste, as well as any credits realized through the sale and use of uranium, plutonium, heavy water and other materials.

Table III presents an outline of the IAEA account system used in preparing a summary of the nuclear fuel cycle costs for light water and heavy water reactors. Accounts 150 and 151 include heavy water supplies and services and are to be used only if these are included in the fuel costs, otherwise they may be included as capital investment costs in account 27. Accounts 160 and 161 (for the supply of heavy water replacement quantities and related services), and 171 (for the financial costs of heavy water), may be included in the O&M costs.

4.2.3. O&M costs account system

The O&M costs include all non-fuel costs, such as costs of plant staffing, consumable operating materials (wear parts) and equipment, repair and interim replacements, purchased services and nuclear insurance. They also include taxes and fees, decommissioning allowances and miscellaneous costs. In addition, the costs of general and administrative support functions and the cost of providing working capital for plant O&M are included. Other O&M costs have to be calculated separately by the owner. The O&M costs are specific to every nuclear reactor and should be included in the overall bid evaluation. Table IV presents an outline of the IAEA O&M costs account system.

TABLE III. STRUCTURE OF THE IAEA NUCLEAR FUEL CYCLE COSTS ACCOUNT SYSTEM

Account number	Account title
100	Fuel assembly, supply, *first core*
101	Uranium supply
102	Conversion
103	Enrichment
104	Fuel assembly fabrication
105	Supply of other fissionable materials
110	Services, *first core*
111	Fuel management (U, Pu, Th)
112	Fuel management schedule
113	Licensing assistance
114	Preparation of computer programs
115	Quality assurance
116	Fuel assembly inspection
117	Fuel assembly intermediate storage
118	Information for the use of third party fuel
120	Fuel assembly, supply, *reloads*
121	Uranium supply
122	Conversion
123	Enrichment
124	Fuel assembly fabrication
125	Supply of other fissionable materials

TABLE III. (cont.)

Account number	Account title
130	Services, *reloads*
131	Fuel management
132	Fuel management schedule
133	Licensing assistance
134	Preparation of computer programs
135	Quality assurance
136	Fuel assembly inspection
137	Fuel assembly intermediate storage
138	Information for the use of third party fuel
140	Reprocessing of irradiated fuel assemblies
141	Credits for uranium, plutonium and other materials
142	Final disposal of fuel assemblies (in the case of no reprocessing)
143	Final waste disposal
150	Heavy water supply, *first charge* (if not included in capital investment costs)
151	Heavy water services, *first charge* (if not included in capital investment costs)
160	Heavy water supply, *replacement quantities* (if not included in O&M costs)
161	Heavy water services, *replacement quantities* (if not included in O&M costs)
170	Financial costs of the nuclear fuel cycle
171	Financial costs of heavy water (if not included in capital or O&M costs)

TABLE IV. STRUCTURE OF THE IAEA O&M COSTS ACCOUNT SYSTEM

Account number	Account title
800	Wages and salaries for engineering and technical support staff, and O&M and administration staff
810	Consumable operating materials and equipment
820	Repair costs, including interim replacements
830	Charges on working capital
840	Purchased services
850	Insurance and taxes
860	Fees, inspections and review expenses
870	Decommissioning allowances, if not included in capital costs (account 54)
880	Radioactive waste management costs
890	Miscellaneous costs

4.2.4. Definition of the IAEA NPP TCIC account system

The following paragraphs (related to Table II) present a summary description of the items of materials, equipment, facilities, labour, quality assurance procedures and services included in each account.

For details see Annex I, which contains a breakdown of the accounts. As noted previously, accounts 22–27 include costs of materials and labour for components and systems, engineering and documentation associated with the manufacture of these components and systems in the factory, and the assembly of some components at the plant site. The costs of labour during construction and erection, as well as the costs of site supervision, are included in accounts 35–39, as appropriate.

Base costs

Account 21. Buildings and structures at the plant site

Account 21 comprises the costs of:

- Site preparation and land reclamation;
- Initial clearing of land before grading and start of construction;
- Access roads to the site boundary;
- Security installations and boundary fences;
- Sanitary installations, yard drainage and storm sewer systems;

- Site improvements, including waterfront structures, harbours and cranes, retaining walls, embankments, sidewalks, parking areas and landscaping;
- Cable and pipe ducts;
- All plant buildings, including:
  —Reactor building with foundations and containment, as well as special equipment such as airlocks;
  —Reactor auxiliary building;
  —Turbine building with the turbine generator foundation and transformer structures;
  —Electrical and water treatment buildings;
  —Emergency diesel generator building;
  —Emergency feed diesel generator building;
  —Administration building.

Account 22. Reactor plant equipment

Reactor plant equipment costs comprises the costs of the reactor system; the primary heat transport system, including steam generators and parts of the main steam and feedwater systems, as well as reactor coolant pumps and drives; the reactor coolant system and piping; the pressurizing system; the maintenance in-service and lifting equipment; the reactor auxiliary and ancillary systems; the engineered safety systems; and the nuclear fuel handling and storage systems. Excluded are annunciation equipment, radiological instrumentation, fixed radiation and contamination monitors, I&C equipment, the reactor protection system and all shielding except that which forms an integral and original part of a piece of equipment.

Account 23. Turbine generator plant equipment

Account 23 comprises the costs of the turbines, generators and condensers, together with the related systems and auxiliary equipment, including the turbine bypass and moisture separator systems, the condensate systems, the feedwater and main steam systems, as well as other turbine plant equipment, including piping, the central lubrication service system and standby exciters, maintenance and lifting equipment, drainage systems and other secondary side systems. For dual purpose plants, the costs of intermediate heat transfer systems may be covered under this account.

Account 24. Electrical equipment and I&C plant equipment

Account 24 comprises the costs of all electrical power equipment, from the main generator terminals to the high or low voltage side of the main output transformer, and all electrical equipment required for auxiliary power, emergency power (converters, batteries), emergency diesel generator system, and standby generation and distribution of power to the station loads. This account also includes the costs of the station service transformer and the standby transformer, wiring and cabling, cable conduit, troughs and junctions, cabling and wiring, cabinets, cubicles and lighting. It includes all equipment associated with conventional and nuclear I&C, the reactor protection system, the reactor in-core/ex-core instrumentation, the radiation monitoring system, the main control room, the computer system and others. The account may include the costs of the main transformer and high voltage switchgear.

Account 25. Water intake and heat rejection

Account 25 comprises the costs of the water intake and discharge structures; equipment for the heat rejection system, including intake and discharge conduits, the skimmer wall, water intake common facilities, circulating water systems, condenser cooling water supply and discharge systems, and service cooling water for the secured plant and the conventional plant. This account also includes the auxiliary installation necessary for the operation of the above mentioned systems.

Account 26. Miscellaneous plant equipment

Account 26 comprises the costs of the heating, ventilation and air-conditioning (HVAC) system; fire protection and fire fighting systems for buildings and yard structures; air and water service systems; transportation equipment; lifting equipment for systems not included in other accounts; the auxiliary heating system; communication equipment; furnishing and fixtures; shop and laboratory equipment; and dining and cleaning equipment. This account covers the cost of all equipment and systems, including piping, not included in other accounts.

Account 27. Special materials

Account 27 comprises the costs of special materials, including the initial supply of coolant, moderator and/or reflector materials and special heat transfer fluids (gases, liquids) or metals and, where applicable, reactor grade graphite for gas cooled reactors, reactor grade heavy water, helium gas for high temperature reactors, nitrogen gas for fast breeder reactors, and CO_2 for Magnox and advanced gas cooled reactors. The owner may lease the D_2O inventory and account for the lease costs in a similar way as for other costs of that kind (see also accounts 150, 151, 160, 161, 170, 171).

Account 28. Simulators

Account 28 comprises the costs of the training simulator hardware and software. The training costs should be accounted for under account 403 (refer to Annex I).

Account 30. Engineering, design and layout services provided by the supplier(s) and/or the A/E at the home office(s)

Account 30 comprises the costs of engineering activities employed in the design and layout of components, systems, buildings and structures, which are performed by the supplier(s) and/or the A/E at their home offices. This includes mainly the costs of basic design, detailed design, design review, procurement, quality assurance and interface engineering.

Account 31. Project management services provided by the supplier(s) and/or the A/E at the home office(s)

Account 31 comprises the costs of management services, covering the co-ordination of work within the supplier(s)' and/or the A/E organizations, as well as the co-ordination of interfaces between supplier(s)' staff and owner's staff and, as far as appropriate, with the regulatory authorities and site management staff at their home offices.

Account 32. Engineering, design and layout services provided by the supplier(s) and/or the A/E at the plant site

Account 32 comprises the costs of engineering activities employed in the design and layout of components, systems, buildings and structures, which are performed by the supplier(s) and/or the A/E at the plant site. This includes mainly the costs of basic design, detailed design, design review, procurement, quality control and interface engineering.

Account 33. Project management services provided by the supplier(s) and/or the A/E at the plant site

Account 33 comprises the costs of managing the co-ordination between different site contractors, the owner and the licensing authorities, which is performed by the supplier(s) and/or the A/E at the plant site.

Account 34. Construction site supervision provided by the supplier(s) and/or the A/E

Account 34 comprises the costs of site supervision of construction work undertaken by the supplier(s) and/or the A/E within their scope of supply and responsibility when such construction or erection work is performed under separate contract(s) with the owner.

Account 35. Construction labour provided by the supplier(s) and/or the A/E or construction companies at the plant site

Account 35 comprises the costs of labour incurred during plant construction and erection, including site supervision of all equipment, structures, components and systems of the supplier(s) and/or the A/E or other construction companies at the plant site (see account 38 for construction and installation materials).

Account 36. Commissioning services provided by the supplier(s) and/or the A/E at the plant site

Account 36 comprises the costs of commissioning services performed by the supplier(s) and/or the A/E at the plant site, including the provision of relevant documentation.

Account 37. Trial test run services provided by the supplier(s) and/or the A/E

Account 37 comprises the costs of test run services performed by the supplier(s) and/or the A/E, including the provision of relevant documentation.

Account 38. Construction facilities, tools and materials at the plant site

Account 38 comprises the costs of construction facilities, tools and materials necessary for construction, and installations provided by the supplier(s), the A/E or the construction company at the plant site. This includes the costs of dismantling the construction facilities and tools, and the costs of their return to the country of the supplier or the A/E, as appropriate. This account also includes the costs of providing electrical energy, fuel, water and sewage disposal for the construction facilities.

Account 39. Commissioning materials, consumables, tools and equipment at the plant site

Account 39 comprises the costs of commissioning materials, consumables, tools and equipment necessary for the execution of commissioning work at the plant site and which are used by the supplier(s) or the A/E. This may include the costs of covering losses of special materials, such as D_2O, Na, He and CO_2. This also includes the costs of providing electrical energy, fuel, water and sewage disposal up to the commercial operating date.

Account 40. Staff training, technology transfer and other services

Account 40 comprises the costs of staff training, technology transfer, simulator training and other services delivered by the supplier(s) and/or the A/E. Technology transfer costs mainly apply to a large NPP programme; they may be partly accounted for by a single unit for comparison purposes. Only those costs which have an impact on the specific plant should be considered. Technology transfer also benefits other areas of the national economy of the recipient country. These costs are always difficult to estimate and quantify and should be obtained on the basis of the best effort.

Account 41. Housing facilities and related infrastructure

Account 41 comprises the costs of the housing facilities and the related infrastructure provided by the supplier(s) and/or the A/E. This may include the costs of supplying electrical energy, air-conditioning, water and sewage disposal to housing provided for personnel employed by the supplier(s) and/or the A/E.

Supplementary costs

Account 50. Transportation and transportation insurance

Account 50 comprises the costs of transportation of equipment and materials, including land, air or marine insurance, as appropriate, from the point of origin to the point of delivery, as specified.

Account 51. Spare parts

Account 51 comprises the costs of inventory spare and wear parts, at the date of commercial operation, provided by the supplier(s) and/or the A/E.

Account 52. Contingencies

Account 52 comprises allowances for all unexpected costs resulting from unforeseeable events up to the date of commercial operation which are not in the supplier's scope and which are related to the other accounts. This account may include costs of repair, disassembly, return transportation to the supplier, and reinstallation, if not specifically included in the supplier(s)' contract. It does not include financial cost contingencies.

Account 53. Insurance

Account 53 comprises allowances for insurance costs other than transportation insurance included in account 50, such as nuclear liability insurance during commissioning and operation by the supplier(s)' staff, storage insurance, workman's compensation insurance, combined property damage insurance, comprehensive general liability insurance against the risk of fire and nuclear incidents, automobile liability insurance and trade union insurance.

Account 54. Decommissioning costs

Account 54 comprises the costs of decommissioning the NPP, if not included in the O&M costs (account 870). For a description of these costs the reader should refer to Section 4.2.6.

Financial costs

Account 60. Escalation costs

Account 60 comprises allowance for the escalation of costs resulting from inflation and is calculated on the basis of price adjustment formulas submitted by the bidders using labour, materials and other official indices. The sources for the definition of these indices are official national publications and the publications of individual authorities (OECD, World Bank, etc.).

Account 61. IDC

Account 61 comprises the accumulated money disbursed to pay off interest on the capital invested in the plant during construction. Associated with every project are financial costs related to the use of capital. The financing terms cover the conditions and costs of the loans offered by the different suppliers and/or lending agencies (banks, credit institutions, etc.) for the scope of supply and services contained in the relevant bids.

Account 62. Fees

Account 62 comprises the cost of various expenses incurred in securing financing, such as commissioning, management and insurance fees.

Owner's costs

Account 70. Owner's capital investment and services costs

Account 70 comprises the costs of land reclamation as well as the costs of installations, services and obligations to be contracted, supplied or incurred by the owner and which are not included in the other accounts.

This may include costs related to the following:

- Land and land rights;
- On-site and off-site infrastructure (e.g. camp construction, electricity and water supplies, telecommunications);
- Buildings, workshops, garages, canteen and information centre;
- Main transformer (if not included in account 24), and switchyard;
- Administration and service costs for the above installations;
- Equipment, machine tools for workshops, hand tools and instruments;
- Storage of equipment, fuel and/or heavy water beyond that of the initial contract;
- Operating the plant from first criticality to the commercial operation date;
- Spare parts and consumables for the equipment and tools;
- Insurance, taxes, fees, licensing, personnel and additional training (if applicable).

Account 71. Escalation of owner's costs

Account 71 comprises allowance for the escalation of costs incurred by the owner as a result of inflation and is calculated on the basis of labour, materials and various official indices.

Account 72. Financing of owner's costs

Account 72 comprises the costs incurred by the owner in financing the capital investment and services costs (account 70), including escalation and interest, rate of exchange losses, and fees, as appropriate.

4.2.5. Definition of the IAEA nuclear fuel cycle costs account system

The following paragraphs (related to Table III) present a summary description of the items of materials, equipment, facilities and services included in each account.

Account 100. Fuel assembly supply, *first core*

Account 100 comprises the costs of: uranium supply (including exploration, mining and milling); conversion; enrichment, if appropriate; fuel assembly fabrication; supply of other nuclear fuel materials, such as Pu and Th, including transportation and transportation insurance, as applicable.

Account 110. Services, *first core*

Account 110 comprises the costs of: fuel management and fuel management schedule; licensing assistance to comply with regulatory requirements; preparation of computer programs (e.g. in-core fuel management to optimize burnup); quality assurance; fuel inspection and intermediate storage; information for the use of third party fuel.

Account 120. Fuel assembly supply, *reloads*

Account 120 comprises the costs of: uranium supply for refueling; conversion; enrichment; fuel assembly fabrication; supply of other nuclear fuel materials, such as Pu and Th, including transportation and transportation insurance as appropriate.

Account 130. Services, *reloads*

Account 130 comprises the costs of: fuel management and fuel management schedule for refueling; licensing assistance; preparation of computer programs; quality assurance, audits and design reviews; fuel assembly inspection and repair; fuel assembly intermediate storage; information for the use of third party fuel.

Account 140. Reprocessing of irradiated fuel assemblies

Account 140 comprises the costs of: reprocessing operations for separating the remaining uranium and plutonium, if applicable; plutonium/uranium conversion to PuO_2; treatment of high level radioactive waste, as appropriate.

Account 141. Credits for uranium, plutonium and other materials

Account 141 comprises the credits for the nuclear fuel (U, Pu and others) during the period being analysed.

Account 142. Final disposal of fuel assemblies

Account 142 comprises the costs of final disposal of the spent fuel in the case where no reprocessing takes place.

Account 143. Final waste disposal

Account 143 comprises the costs of final disposal of radioactive waste from reprocessing.

Account 150. Heavy water supply, *first charge* (if not included in capital investment costs)

Account 150 comprises the costs of heavy water supply for the moderator and heat transport systems, including heavy water inventory for conditioning and upgrading equipment; allowance for losses during commissioning up to commercial operation date; and costs of transportation and transportation insurance, as appropriate.

Account 151. Heavy water services, *first charge* (if not included in capital investent costs)

Account 151 comprises the costs of: heavy water management, including delivery schedules; licensing related activities to comply with transportation requirements; quality assurance; chemical and physical improvements and control, including isotopic concentration; export permits.

Account 160. Heavy water supply, *replacement quantities* (if not included in O&M costs)

Account 160 comprises the cost of heavy water needed to replace losses and the costs in monitoring the reactor grade heavy water inventory at the site, including transportation and transportation insurance, as appropriate.

Account 161. Heavy water services, *replacement quantities* (if not included in O&M costs)

Account 161 comprises the costs of: heavy water management, including delivery schedules; licensing related activities to comply with transportation requirements; quality assurance; chemical and physical improvements and control, including isotopic concentration; export permits.

Account 170. Financial costs of the nuclear fuel cycle

Account 170 comprises the costs associated with escalation, interest and fees on the money borrowed to finance the nuclear fuel cycle.

Account 171. Financial costs of heavy water (if not included in capital or O&M costs)

Account 171 comprises the costs associated with escalation, interest and fees on the money borrowed to finance heavy water supplies.

4.2.6. Definition of the IAEA O&M costs account system

The following paragraphs (related to Table V) present a summary description of cost accounts which include both fixed and variable O&M costs.

Account 800. Wages and salaries for engineering and technical support staff, and O&M and administration staff

Account 800 comprises the costs of owner's staff in single unit or multiunit plants.

Account 810. Consumable operating materials and equipment

Account 810 comprises the costs of all consumable materials, such as resins, chemicals, gases, drums, casks, materials for the disposal of waste, oil lubricants, filters, neutron detectors and recorder chart paper, as well as heavy water make-up (if not included in account 160).

Account 820. Repair costs, including interim replacements

Account 820 comprises the costs of new equipment, materials and labour needed for repair.

Account 830. Charges on working capital

Account 830 comprises the costs of annual interest charges on the working capital needed to accommodate uneven cash flow demands throughout the year. The plant working capital (excluding that used for fuel) is composed of two parts: the average net cash required for plant operation and the value of the inventory of materials and supplies (this value may be assumed to correspond to an average of three months' consumption).

Account 840. Purchased services

Account 840 comprises the costs of outside services, such as: purchased energy for station needs, research and development for specific applications, safety reviews, training of personnel, meteorological surveys, engineering studies, updating and reviews, in-service inspections, environmental studies, computer programming and application, inspection of pressurized components, film and badge processing, outside maintenance help, refuelling assistance, and storage of low and medium level radioactive waste outside the plant. Also covered are the costs of heavy water supplies and services (if not included in accounts 160 or 161) and heavy water financial costs (if not included in accounts 27 or 171).

Account 850. Insurance and taxes

Account 850 comprises the costs of commercial nuclear liability insurance, government liability insurance, property insurance, replacement power insurance and taxes, as appropriate.

Account 860. Fees, inspections and review expenses

Account 860 comprises the costs of safety, quality, environmental and health inspections, replacement power fees and review expenses.

Account 870. Decommissioning allowance (if not included in capital costs)

Account 870 comprises the cost allowances made to provide funds for covering the future costs of an orderly shutdown of the plant, removal of the nuclear fuel and/or heavy water, decontamination of the systems, placement of the facility under storage, with surveillance for a certain number of years, followed by dismantling of the power plant and removal of all components and civil structures necessary to achieve an unrestricted use of the site.

Account 880. Radioactive waste management costs

Account 880 comprises the costs incurred in the management and disposal of low and medium level radioactive operating waste.

Account 890. Miscellaneous costs

Account 890 comprises the costs of public relations, office supplies, travel, telephones, petroleum products and maintenance of vehicles.

4.3. TECHNICAL BID EVALUATION AND INTERFACES WITH THE ECONOMIC BID EVALUATION

The technical bid evaluation provides the basis for the development of costs related to deficits or surpluses in materials and services occurring when a bid is compared with the BIS or the reference bid (the most complete one). Furthermore, cost figures have to be generated for technical deviations in the designs presented in the different bids.

Normally, the BIS describes a certain type of NPP or plants which can not be easily compared with the plants described in the various bids. The bids will be based on a specific technology that is licensable in the country of origin and which follows the codes, standards, requirements and technical specifications indigenous to that country. Consequently, cost adjustments will be required to reflect the differences in the quantities of components and their related installation and service person-hours. Cost information for these adjustments can be taken from the required cost data tabulated in the bids in accordance with the IAEA account system. If the level of detail of the cost data does not allow direct utilization, the necessary cost information will need to be requested from the bidders. For the evaluation team to successfully compare the different designs from a cost standpoint, the team members must have a high degree of technical experience as the technical differences must be identified first.

Another important aspect of the evaluation process is the impact of differences in plant design and operating characteristics. One of the most difficult tasks is the assessment of differences in such diverse items as:

- Safety requirement,
- Failure criteria,
- Redundancies and diversities in components and systems that mitigate external or internal incidents or accidents,
- Radiological impacts on operating personnel and the plant environment,
- Implications of measures against ‘beyond design basis accidents’,
- Probability figures for the occurrence of severe accidents.

In this area, the evaluation team has to consider both quantitative and qualitative assessment results. Uncertainties have to be identified. With regard to capital investment costs, an appropriate amount for contingencies has to be added.

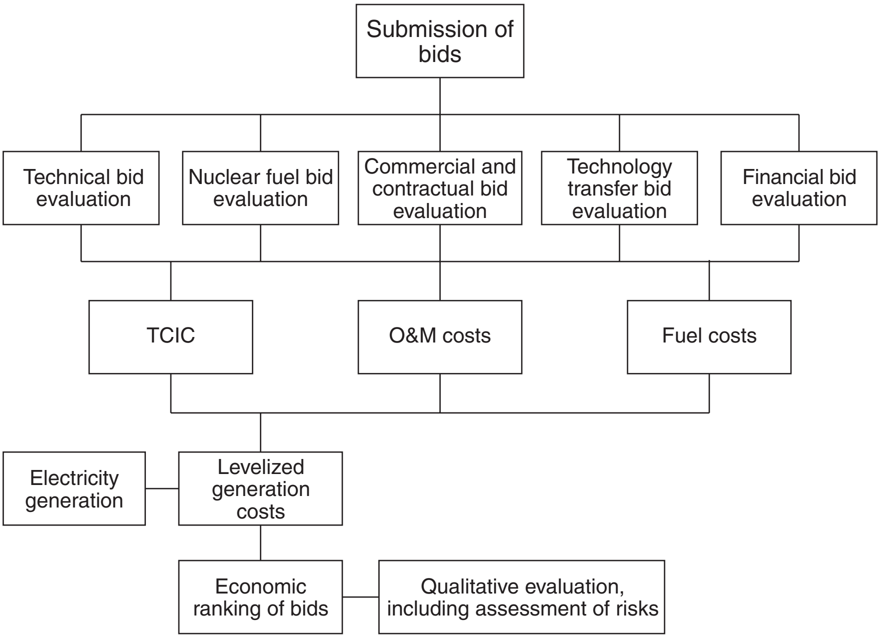

FIG. 4. Interfaces among the various fields of evaluation.

The nuclear fuel costs depend on the mode of operation and the fuel cycle length. The structure of the complete grid dictates the mode of operation, i.e. the NPP mainly operates in base load or is being used also for load following and frequency control.

Normally, the fuel cycle varies in duration from 12 to 18 months, while in some countries a 24 month cycle is adopted. For a long fuel cycle, high enrichment and compensation methods for excess reactivity control are needed. These long fuel cycles require related measures to be taken in the plant maintenance strategies. Long periods of continuous operation severely stress a number of components, requiring appropriate design precautions to be taken. The higher investment costs of an extended fuel cycle have to be carefully assessed in order to evaluate the economic viability.

Figure 4 illustrates the link between the technical and the economic bid evaluation. This report only describes the economic bid evaluation process. However, face to face contacts and exchange of interface information between the economic evaluation team and the other evaluation teams need to be very active and vigorous. The results gained from these analyses constitute an important basis for the entire bid evaluation. Further aspects of the interface between the economic and technical bid evaluations are discussed in Section 7.

4.4. COMMERCIAL AND CONTRACTUAL TERMS AND CONDITIONS

4.4.1. Contract structure and content

A contract usually contains a list of the documents that are part of the contract, the list identifying the priority of the documents. These documents describe the equipment and services, schedules, prices and other general conditions.

The owner should include in the BIS the terms and conditions wanted, including an outline of a draft contract.

4.4.2. Cost adjustment due to commercial and contractual conditions

The contractual approach has a major influence on the commercial and contractual aspects that must be considered in the economic bid evaluation. The evaluation of the contractual conditions offered in the bids fundamentally consists of identifying any exceptions or deviations from the BIS and of assessing their effect and importance in cost terms. If the cost consequences of differences in scope and the significance of items or facts are clear, then cost adjustments are readily obtainable and a direct comparison can be made. Much experience and judgement are required in this procedure. However, if it is not possible to arrive at a quantitative cost figure, a qualitative evaluation is required. A comparison of the offered bids may be made in order to identify the different aspects and the significance of each item. Such items as the financial status and the capabilities of the bidders for similar projects, the sociopolitical and economic situations in the supplier's country, and the risks and advantages or disadvantages involved, may be included in the assessment.

The commercial risks should be carefully identified. The boundaries of responsibility for the scope of supply and services must be defined in detail in order to estimate the risk involved.

4.5. NUCLEAR FUEL CYCLE

4.5.1. Description of the nuclear fuel cycle

The nuclear fuel cycle includes all operations involved in the procurement, processing and fabrication of nuclear fuel, the use of the fuel in the reactor, the storage and/or reprocessing of the spent fuel, and the management, intermediate storage and final disposal of the high level radioactive waste.

For an NPP, the costs of the fuel cycle are a relatively small percentage of the total generation costs, and the cost of the nuclear raw material itself accounts for only

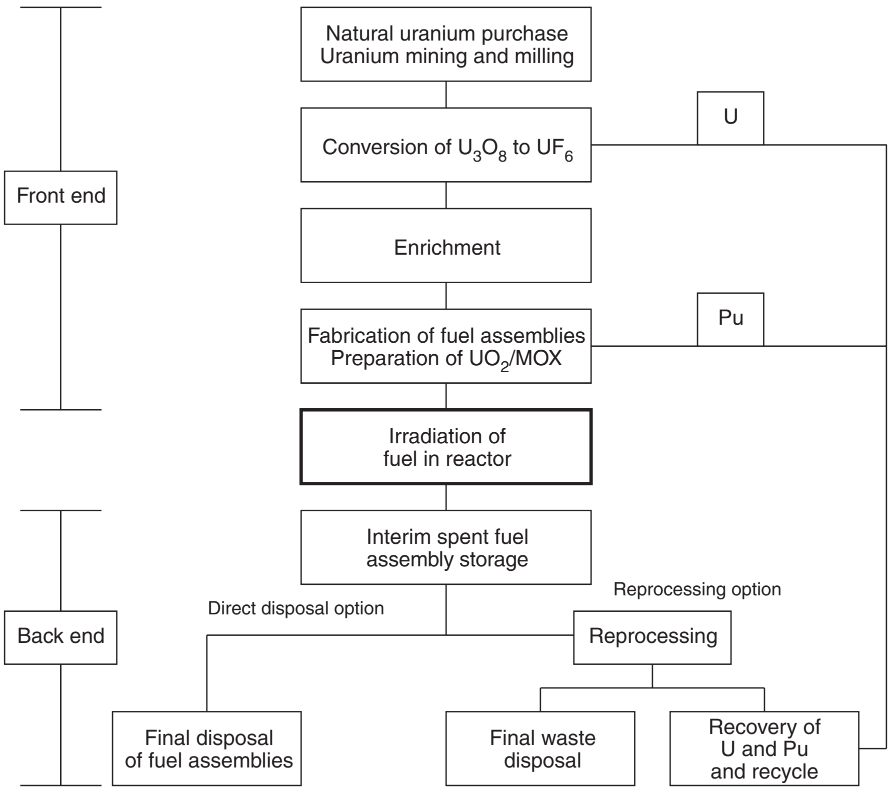

FIG. 5. Generalized schematic diagram of the LWR fuel cycle.

a portion of the nuclear fuel cycle costs. For fossil fuel plants, however, the fuel costs are the major cost component of the total generation costs.

The fuel cycle of an NPP can be divided into three main stages, comprising the following activities:

- Front end activities, ranging from the exploration for and mining of uranium ore to the delivery of fabricated fuel elements to the reactor site.
- Fuel management activities at the power plant, including reception and inspection of fresh fuel, storage of fresh fuel, refuelling of the reactor, in-core fuel management, unloading of spent fuel, inspection and investigation of failed fuel elements, and fuel safeguards procedures and accounting.
- Back end activities, beginning with temporary storage of spent fuel, shipping of spent fuel to away-from-reactor storage, spent fuel reprocessing and waste

management, and ending with the final disposal of the reprocessing waste or of the spent fuel itself.

For a light water reactor (LWR), as shown in Fig. 5, the steps in the nuclear fuel cycle include the exploration for and mining and milling of uranium; the conversion of U_3O_8 to UF_6; the enrichment of ^{235}U to the appropriate level (usually in the range of 2.0–4.5 wt%); fuel pellet fabrication; fuel assembly fabrication and transportation to the plant site; loading of the fuel into the reactor and irradiation of the fuel; spent fuel shipping and reprocessing for recovery of unburned ^{235}U and fissile plutonium; and final disposal of reprocessing waste. Spent fuel is usually stored for several years in spent fuel storage facilities (dry or wet storage) before shipment to centralized immobilization and repository facilities or to reprocessing facilities.

In the once-through cycle (no reprocessing), the valuable uranium and plutonium are not reused. After removal from the reactor, the nuclear fuel is kept in intermediate storage facilities for some time (varying from a couple of years up to several decades). In the long term, spent fuel elements must be conditioned so that permanent storage in deep geological repositories is possible.

In a closed fuel cycle, the spent fuel, after its radioactivity has decayed in temporary storage facilities, is shipped to a reprocessing plant for chemical reprocessing. After chemical reprocessing, the fissile plutonium and the residual uranium can be used to fabricate new fuel elements which can be recycled in a normal LWR or in converter reactors. During chemical reprocessing and refabrication of the fuel, a small fraction of the fissile material (about 1%) remains in the radioactive waste where it is lost.

Figure 6 is a schematic diagram of a heavy water reactor (HWR) fuel cycle. Yellowcake is converted to UO_2 and fuel elements are fabricated from sintered pellets; these fuel elements are then shipped to the reactor site. No enrichment is necessary, although one option may permit a slight enrichment if the enrichment costs are sufficiently low to make this economically attractive.

4.5.2. Bid evaluation aspects of the nuclear fuel cycle

The bids for the nuclear fuel cycle may include all activities from delivery of ore to reprocessing of irradiated fuel or they may contain only some specific components of the scope of supply and services.

According to international practice, the BIS will require fuel assemblies and fuel for a few reload cycles, in addition to the fuel assemblies and fuel for the first core. Depending on the reactor concept offered, the reload fuel may be accounted for either separately or together with the fuel for the first core. Differences in the bids have to be converted into costs, which are the basis of the economic bid evaluation.

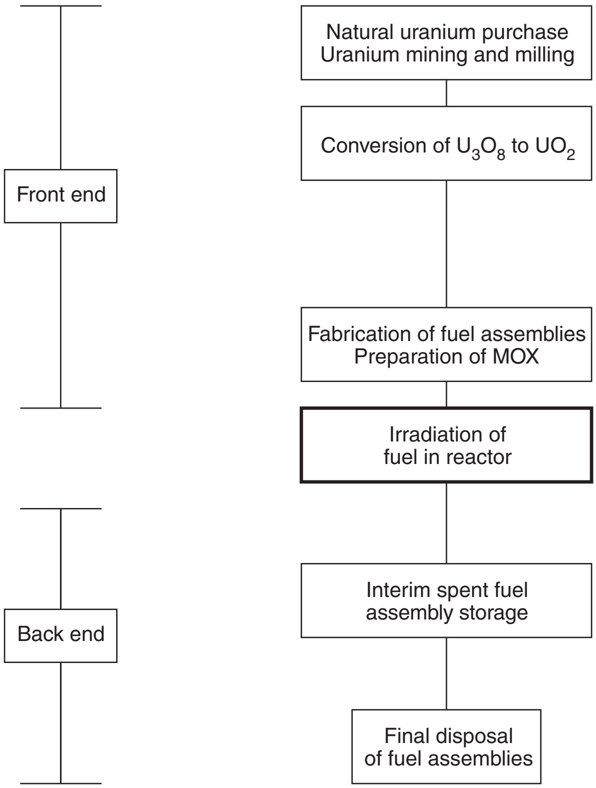

FIG. 6. Generalized schematic diagram of the HWR fuel cycle.

The IAEA nuclear fuel cycle cost account system identifies the different steps in the nuclear fuel cycle (see Table III).

The options available to the owner may range from complete turnkey fuel services to the opposite extreme of having the nuclear fuel cycle broken down into a large number of contracts co-ordinated and financed by the owner.

The purpose of the nuclear fuel cycle bid evaluation is to analyse the bids and compare the offered scope of supply and services with the requirements established in the BIS. The economic bid evaluation must result in nuclear fuel cycle costs which are an integral part of the LDEGC. For the evaluation of these costs, the remainder of the nuclear fuel cycle costs during the economic life of the plant must be estimated. This is an area where great uncertainty exists regarding the estimated values for the nuclear fuel costs and for the nuclear fuel management services costs. This estimate must be made on the basis of best effort.

An important part of the nuclear fuel cycle activities is fuel management services, which has to be analysed and evaluated carefully. Differences in the bids have to be converted into costs or person-months, while the qualitative aspects have to be considered separately.

At present, reprocessing services are available in very few places in the world. In many cases, storage capacities inside or outside the plant are utilized for intermediate storage. The final storage of the high level radioactive waste is mostly achieved through bilateral agreements between countries and may be treated separately from the economic bid evaluation. The costs of reprocessing services, if these are offered as an option, and of intermediate storage capabilities should be evaluated in addition to the NPP costs. In effecting a comparison of the different reactor types (LWR, HWR), the same assumptions have to be made in the nuclear fuel cycle analysis in order to generate an equitable comparison of the nuclear fuel cycle costs.

4.5.3. Economic adjustments

As mentioned before, differences in the specific accounts of the bids should be converted to cost figures and adjusted in order to obtain comparable results. Those portions of the scope of supply and services which are not included in the bid by some suppliers have to be identified and will be subject to adjustment. Other items, such as alternative fuels, for instance MOX fuel, the fuel cycle length (18 months or 24 months) and the option of using slightly enriched fuel for HWRs, should be assessed separately. Cost adjustments may result from this evaluation.

A very important feature is a warranty for long term fuel supply and/or enrichment services, which in most cases is required in the BIS. Cost differences for fuel management services and service equipment offered should be identified in the evaluation, with appropriate cost adjustments being made as required. As mentioned previously, qualitative considerations may also be necessary in order to obtain a complete picture.

4.6. DOMESTIC PARTICIPATION

The available industrial infrastructure and the contractual arrangements will determine the extent of national participation and will thus have an important bearing on the construction cost.

A country pursuing a nuclear programme will usually aim at having its domestic industry participate as much as possible in the construction of NPPs. It will make efforts to develop the industry in order to expand its role in the course of such a programme. The ultimate aim may be that the country’s industry will supply a high percentage of the plant equipment, which from a practical standpoint could lead to self-sufficiency. This could be achieved after construction of a series of plants. Only limited participation can be expected for the first nuclear unit. With this objective in mind, an industry survey should be carried out to identify capabilities and deficiencies in the domestic industry. The result will be a description of improvements needed in the short, medium and long term concerning the quality and quantity of engineering, manufacturing and construction. All these activities require technology transfer between partners in specialized areas of industry and will have an impact on costs. Further details are given in Section 8.

5. EVALUATION METHODS

5.1. INTRODUCTION

The objectives of making an economic comparison of bids are the ranking of alternatives according to costs and evaluating the resulting cost differences. A data flow diagram of the economic bid evaluation process for NPPs is presented in Fig. 7.

The economic bid evaluation is based on the following data and information:

- Bid prices,
- Results of the technical bid evaluation and corresponding interfaces,
- BOP cost estimates,
- Commercial and contractual terms and conditions,
- Economic parameters,
- Financing terms and conditions,
- Local participation and technology transfer,
- Owner’s costs,
- Bids for initial fuel and some reloads,
- Options for further reloads,
- O&M cost estimates,
- Back end cost estimates (spent fuel management and decommissioning).

The IAEA account system can assist in checking the completeness of bids, checking for differences in the scope of supply and services, and evaluating the BOP cost.

The different types of cost which will be incurred during plant construction and during the economic life of the plant may be classified as follows (see Tables II–IV):

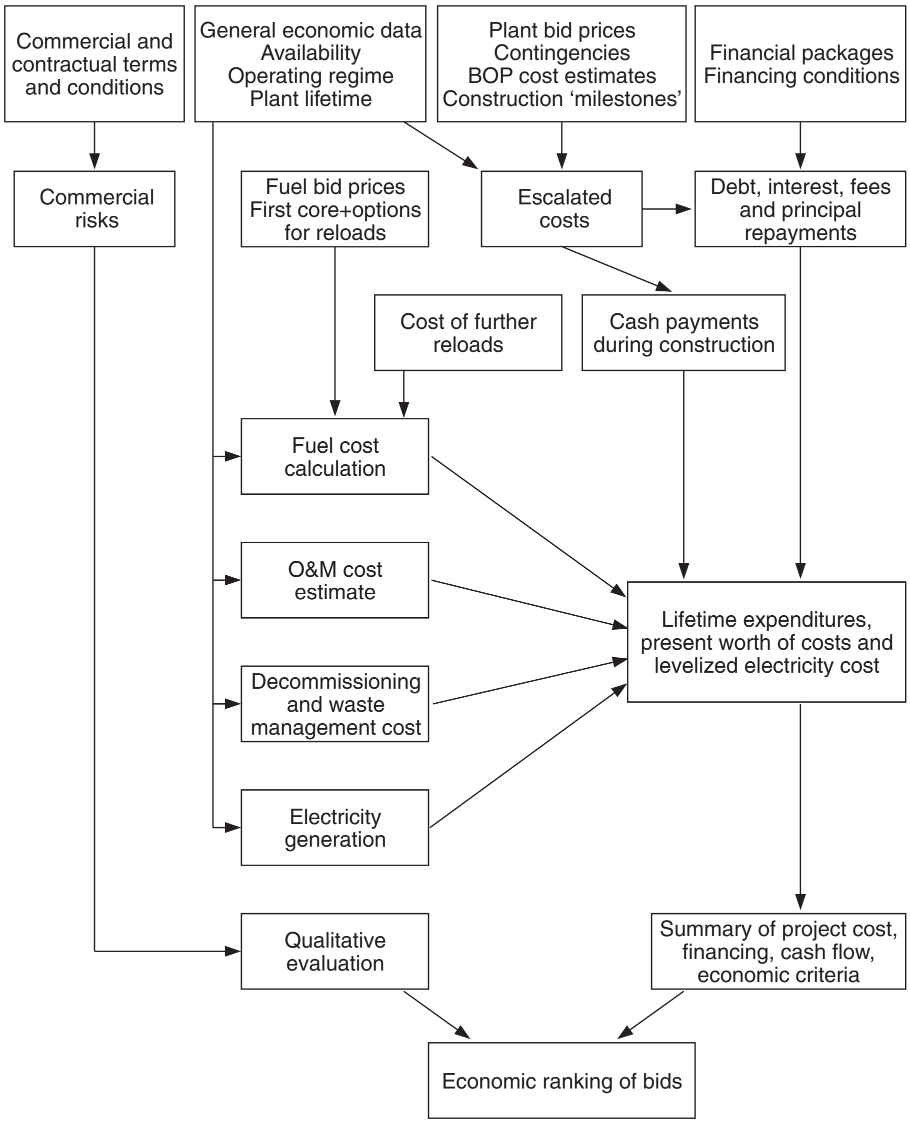

FIG. 7. Data flow diagram of the economic bid evaluation process for NPPs. Note that only the context of major economic evaluation areas is illustrated.

- TCIC,
- Nuclear fuel cycle costs,
- O&M costs.

These costs, which include the technology transfer, waste management and decommissioning costs, have already been discussed in detail in Section 4. Together with the economic parameters, they form the group of data and basic elements necessary for applying the suggested evaluation technique.

Various methods of cost comparison are used to evaluate the economic order of competing bids. The economic bid evaluation will most probably focus on the present worth method and the resulting total plant costs and/or on the LDEGC. The evaluation, which may be performed in either current money or constant money, is discussed in Section 5.3. The breakdown of local and foreign costs also has to be considered.

5.2. CRITERIA FOR ECONOMIC RANKING

Both qualitative and quantitative decision criteria are used for the economic ranking of bids. As a rule, as much as possible of the economic evaluation should be performed in quantitative terms, i.e. in monetary value. A number of criteria, representing a variety of objectives, could be used for ranking the bids.

When several criteria are used, conflicts over the ranking of bids could arise. This situation can be avoided by using a predetermined hierarchy of importance and applying corresponding weighting factors to the criteria.

5.2.1. Qualitative criteria

A qualitative evaluation is necessary for those cases in which the data provided in a bid or the consequences to the owner can not be readily quantified. This may be the case for some risks and benefits to the owner or to the country. For example, the data for technology transfer may be evaluated in qualitative terms (see Section 8). Many points, such as contractual aspects, licensing procedures and the socioeconomic situations in the supplier's and the owner's countries can only be considered in a qualitative manner.

Techniques exist for comparing alternative choices on a relative basis. These techniques allow for the incorporation of judgement and personal values in a logical and structured method. A widely applied technique is to convert qualitative judgements into numerical values.

5.2.2. Quantitative criteria

Some well known and widely applied methods of economic bid evaluation are discussed in this section and in Appendix I. Nevertheless, a method is suggested which is considered to be most suited to the economic bid evaluation of an NPP.

The most common criteria on which to base investment decisions may be classified into two main groups:

- Criteria which consider the expenses without taking into account the time of their occurrence (which constitutes their main disadvantage) and which are based on:
  —Annual cost calculation,
  —Total net cash flow per monetary unit disbursed,
  —Average annual net cash flow per monetary unit disbursed,
  —Pay back or capital recovery time.
- Criteria which do consider the time associated with the expenses, using the discounting procedure to equalize the amounts of money at different moments of time, and which are based on:
  —Present worth values,
  —Internal rate of return.

These approaches are described in Section 5.3.1 and Appendix I.

A major difficulty in the economic evaluation of a project over a long plant life is that the future values of relevant economic parameters are not known. They must either be estimated, or a method must be chosen which does not require estimation. A key parameter is the electricity price in future years, which is required in order to calculate the flow of future revenue for each alternative.

Of the criteria indicated, only two of the present worth based criteria, i.e. the minimum present worth of total plant costs and the LDEGC, do not require this flow for their correct application. The criterion based on the minimum present worth of total plant costs is the simplest of all of the criteria mentioned. However, it does not take into account the possible variations in energy production for the different bids. Therefore, the method suggested in this report is that by which the LDEGC are obtained.

5.3. ECONOMIC EVALUATION METHODOLOGY

5.3.1. LDEGC

As discussed above, the suggested ‘yardstick’ to use for the economic ranking of bids are the LDEGC (C_{lev}). The term C_{lev} is defined as the rate for each unit of electrical energy which must be charged in order to recover exactly the total plant lifetime costs, taking into account the time value of money. The total plant lifetime costs include capital investment costs, fuel cycle costs and O&M costs.

In other words, the sum of present worths (PW) of lifetime electricity revenues will equal the sum of the PWs of lifetime costs when each kilowatt-hour (kW·h) is sold at C_{lev} monetary units:

$$\sum \text{PW (lifetime electricity revenues)} = \sum \text{PW (lifetime costs)} \quad (1)$$

$$\sum_{t=T_O}^{T_L} \frac{C_{lev} E_t}{(1+d)^{t-T_D}} = \sum_{t=T_B}^{T_E} \frac{C_t}{(1+d)^{t-T_D}} \quad (2)$$

where: C_t = total plant cost (capital, fuel, O&M) in year t
E_t = energy produced (kW·h) in year t
d = discount rate
T_B = bid reference date
T_D = date to which discounting is performed
T_O = date of start of commercial generation
T_L = date of end of plant life
T_E = date of end of decommissioning.

Note that the costs accumulated through T_E also include the discounted values of costs spent before T_O (plant construction) and committed to be spent after T_L (decommissioning costs).

This definition of LDEGC may appear at the same time to be rather simple and rather abstract. Its application, however, presupposes extensive calculations for determining the distribution of costs over time (C_t) and the schedule of future energy production (E_t).

Figures 8 and 9 show schematically the cumulative cash requirements and revenues for the key periods during the project life of an NPP.

Since by definition C_{lev} is constant, Eq.(2) can be transformed to calculate C_{lev}:

$$C_{lev} = \frac{\displaystyle\sum_{t=T_B}^{T_E} \frac{C_t}{(1+d)^{t-T_D}}}{\displaystyle\sum_{t=T_O}^{T_L} \frac{E_t}{(1+d)^{t-T_D}}} \quad (3)$$

The bid which offers the minimum value for C_{lev} is economically preferable.

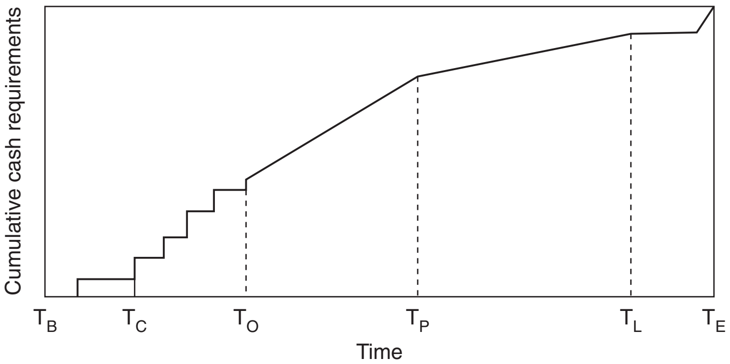

FIG. 8. Cumulative cash requirements. T_B: bid reference date; T_C: start of construction; T_O: start of commercial operation; T_P: end of payback period; T_L: end of economic life; T_E: end of decommissioning.

5.3.2. Evaluation in constant or current money

The analyst has the choice of making an economic analysis in current money by including the effect of inflation or in constant money by disregarding the effect of inflation. Current money means money as spent or earned. Future payments in current money are calculated using nominal escalation (or inflation) and nominal interest rates. Constant money means money of constant value, i.e. as if no general inflation existed. Future payments in constant money are calculated using real escalation and real interest rates. These real rates are related to the nominal rates according to the following:

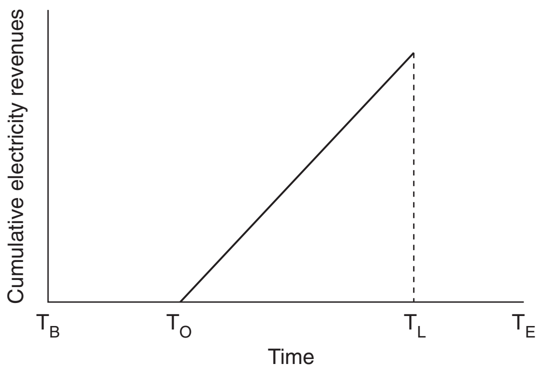

FIG. 9. Cumulative electricity revenues.

$$(1 + \text{nominal rate}) = (1 + \text{real rate})\ (1 + \text{inflation rate}) \qquad (4)$$

The relationship between real escalation, nominal or apparent escalation and inflation is as follows:

$$(1 + e_n) = (1 + e_r)\ (1 + e_i) \qquad (5)$$

where: e_n = nominal or apparent escalation rate
e_r = real escalation rate
e_i = inflation rate

The nominal and real discount rates are related as follows:

$$(1 + d_n) = (1 + d_r)\ (1 + e_i) \qquad (6)$$

where: d_n = nominal discount rate
d_r = real discount rate
e_i = inflation rate

If a present value analysis is performed by using a constant monetary value, the payments are assumed to increase solely according to the real escalation rate (e_r). These constant money payments are discounted using a real discount rate (i.e. net of inflation).

The major drawback of a constant monetary analysis is that it is cumbersome to perform when loans are included in the economic study, since the terms of loans are always expressed in current monetary value. Repayment must be made in current monetary units and hence such units must be used in the financial analyses and the economic bid evaluation. Another drawback is that the actual future expenses (which will include inflation) are not reflected.

In general, bid evaluations and other engineering economic analyses are made in current money because, in a society of changing monetary values, this option affords more insight into the future effects on utility customers. On the other hand, the constant money analysis does offer a view of changing cost patterns without the inflation effect and therefore may be appropriate in some cases. Working in constant money has the advantage of making the analysis essentially independent of the inflation rate. Cost trends due to real price escalation are clearly visible. Constant money analyses referenced to a nearby point in time result in costs presented in money that has a purchasing power close to current experience; value judgements are thus easier to make.

The present worth of costs, PW(C), may be calculated either in constant or in current money. Care should be taken about the consistency of costs and discount rate.

Should the cost be expressed in constant money, then the discount rate (d) must be the real one (d_r, inflation free). If the costs are expressed in current money, the nominal discount rate (d_n) must be used.

It is important to note that:

- In a constant money analysis, the present worth of total plant lifetime costs, PW(C), will be expressed in constant money of time T_B (bid reference date).
- In a current money analysis, PW(C) will be expressed in money of time T_D (the date to which discounting is performed), which may be different from time T_B. For purposes other than bid evaluation, it is often selected as time T_O (start of commercial operation).

In a current money analysis, the expenses C_t in year t can be calculated from:

$$C_t = C_{t_B}(1 + e_i)^{t-T_B} \tag{7}$$

where: e_i = inflation rate
T_B = bid reference date
C_{t_B} = expenses occurring in year t, but expressed in money of the bid reference date T_B

Hence, the PW(C) of total plant lifetime costs (the numerator in Eq. (3)) may be written as follows (d_r being the real discount rate):

$$\text{PW(C)} = \sum_{t=T_B}^{T_E} \frac{C_{t_B}(1+e_i)^{t-T_B}}{[(1+e_i)(1+d_r)]^{t-T_D}} \tag{8}$$

$$\text{PW(C)} = \sum_{t=T_B}^{T_E} \frac{C_{t_B}(1+e_i)^{T_D-T_B}}{(1+d_i)^{t-T_D}} \tag{9}$$

$$\text{PW(C)} = (1+e_i)^{T_D-T_B} \sum_{t=T_B}^{T_E} \frac{C_{t_B}}{(1+d_r)^{t-T_D}} \tag{10}$$

In a current money analysis, PW(C) will be expressed in money of the discounting date, T_D, which may be different from T_B (for example, T_O, start of commercial operation). This is due to the fact that in Eq. (8), inflation trends beyond the discounting date that are included in C_t are cancelled out by the same inflation factor that is included in the nominal discount rate (d_n).

In most analyses, the date to which discounting is performed (T_D), is either T_B or T_O (start of commercial operation). Although both approaches are perfectly acceptable, one advantage of selecting T_B is that Eqs (8–10) are simplified and PW(C) is expressed in constant money of the bid reference date T_B. This approach is recommended and is used in the BIDEVAL-3 computer software for economic bid evaluation.

In a current money analysis, the LDGEC (C_{lev}) can be calculated either in constant money of the discounting date or in mixed year currency, i.e. including inflation. C_{lev} is obtained in mixed year currency when the nominal discount rate is used in Eq. (3) both in the numerator (for discounting costs) and in the denominator (for discounting the electricity generation). C_{lev} is obtained in constant money when the nominal discount rate is used in the numerator of Eq. (3) (for discounting costs) and the real discount rate is used in the denominator of Eq. (3) (for discounting the electricity generation).

If C_{lev} is expressed in constant money, it will appear close to current electricity prices, thus making it easier to understand. Further aspects of constant and current money analysis are discussed in Appendix I.

5.4. ECONOMIC PARAMETERS

Relevant economic parameters for the economic evaluation include:

- Inflation, escalation, discount and interest rates;
- Project time and project schedule;
- Economic life;
- Reference date of prices (often the bid reference date);
- Date to which discounting will be performed (start of commercial operation of the plant or bid reference date);
- Exchange rates of currencies (reference currency versus foreign currencies).

Their use for the economic evaluation is explained below.

5.4.1. Escalation and inflation rates

Inflation is measured by the change in the prices of a basket of goods and services over time, generally performed at a national level. Escalation is measured by the change in the prices of specific commodities, e.g. steel, cement, construction labour.

The increase in the costs and in the offered bid prices which will occur during the construction period have to be estimated and considered by the owner of the NPP. This increase must be taken into account when the total financing requirements for the project are established. The prices offered in the bids are usually subject to escalation. This is taken into account by using a price adjustment formula (PAF), which is part of the bidding document.

The capital investment costs, or their constituent parts, may be subject to escalation. This is a function of the labour and material cost indices in the supplier(s)' countries and/or in the buyer's country, depending on the origin of the supply. The economic bid evaluation should be based on estimates of the future values of these cost indices, which may be obtained from official sources.

The following data are usually known or can be estimated:

- The base price of an item on a given date (t_1), which may differ from the reference date of the monetary unit;
- The date of payment for this item if the total sum is paid, or the schedule of payments if they are spread over a period of time;
- A PAF which is applied to the base price or to each term of payment.

Price escalation is, in principle, related to materials and labour indices and may be represented by the following PAF:

$$P(t) = P(t_1) \times [A + B\,(L_t/L_1) + C\,(M_t/M_1)] \qquad (11)$$

where:
- $P(t)$ = adjusted price of payment to be made on date (t), taking into account the price escalation
- $P(t_1)$ = offered price or payment corresponding to the reference date (t_1)
- L_t = labour (wages) index as determined or reported by the official source on the date of payment
- L_1 = specific labour index on the reference date (t_1) which defines the base price
- M_t = material index on the date of payment
- M_1 = specific materials index (e.g. for steel) on the reference date (t_1) which defines the base price

A, B and C are coefficients whose sum is equal to 1. Coefficient A is the fixed portion (not subject to escalation); coefficients B and C are the escalated portions. Thus, if the particular payment is not subject to escalation, coefficient A is unity and coefficients B and C are both zero.

The coefficients included within the square brackets refer to the fixed portion, the labour portion and the materials portion, respectively. These coefficients are subject to contract negotiations and mutual agreement. The time and frequency of price adjustments offered by the bidders may differ.

In order to forecast the evolution of the labour and material cost indices, an in-depth analysis of historical trends and forecasting techniques should be part of the sensitivity analysis.

The offers from the various bidders often present different concepts related to:

- The weight of materials and labour in the PAFs,
- The determination of another price basis within the loan period,
- Monetary fluctuations.

These particular aspects and concepts make it necessary to analyse and carefully evaluate these factors with respect to their influence on the energy generation costs.

5.4.2. Discount rate

The discount rate is an economic parameter similar to a rate of interest. It reflects the time value of money that is used to convert benefits and costs occurring at different times to equivalent values at a common date (present value analysis). For economic bid evaluation purposes, this parameter is needed in order to discount all costs and benefits to a common reference date, which is usually the bid reference date (T_B). This reference date may also be the effective date of contract signing or a date fixed in the BIS.

The discount rate may be set by government policy or may be derived from a consideration of capital markets. Theoretically, it reflects the opportunity cost of capital being invested, i.e. the return that could be achieved with the most productive alternative investment open to the country or to the investing organization. This can be assessed objectively by examining the range of investment options. Alternatively, for policy reasons, a particular target return may be set, for example, a target can be used to ensure that public sector investment is no less productive than private sector investment. This may be done by setting the discount rate equal to the return to be expected in real terms, i.e. excluding inflation. Since the choice of the discount rate can have a strong influence on which public policies and projects can be supported by a cost–benefit analysis and which can not, it is a matter of concern to politicians as well as policy analysts.

There may be good reason for developing countries that have capital constraints to use a real discount rate which is substantially higher than those used in industrialized countries. This would reflect not only their capital scarcity but also the possibly greater profitability of their new investment projects. For these new projects, the developing countries have to find funds, and consequently there is competition for the limited financial resources available. However, the higher the discount rate, the lower the value of future benefits in comparison with current benefits. A high discount rate will favour projects with short term profitability.

In determining the appropriate discount rate in a current money analysis, care must be exercised when including the effect of inflation. It is possible that high inflation rates may influence the value of the real discount rate (d_r), since this value is based on a certain level of investment risk and high inflation rates may change the level of risk.

5.4.3. IDC

The IDC reflects the financial costs associated with the use of capital during plant construction. Money borrowed or committed for project implementation must be paid back or recovered with interest. Hence, IDC is the accumulated money disbursed by a utility to pay off interest on the capital invested in the plant during construction. A generic term, widely used, is allowance for funds used during construction. This term encompasses the IDC as well as certain brokerage fees and other expenses related to the procurement of loans.

The interest rate is set by the terms of the loan. The nominal interest rate should be stated in the loan agreement. As money is committed to a project, interest is calculated from the cash flow for the project. The cash flow, together with the effective nominal interest rate (refer to Glossary), should be investigated in detail during the bid evaluation process.

As a general rule, the owner of an NPP must pay the following financing charges:

- Interest on the amount of money drawn from the total loan, committed according to the progress of construction.
- Commitment fees on the total or remaining amount of the loan. Payment starts after signing of the loan agreement and extends over the disbursement period (e.g. 0.25% per year on the balance of the committed funds not yet drawn).
- Management fee to be paid at the beginning of the loan period for all operations related to loan management (e.g. 0.3% of the committed funds).

On the basis of the construction schedule presented by each bidder, the monthly, quarterly or other periodic disbursements are evaluated in terms of interest and commitment fees for the total loan or a fraction of it. The construction schedule normally reflects the requirements of the BIS.

A common approach for calculating the IDC is discussed in the following paragraphs. The interest rates for all local and foreign financing packages should be stated separately.

The calculation approach assumes that an amount of money is borrowed at the beginning of a given year. To determine the interest charges on this money, the amount borrowed is multiplied by the factor

$$(1 + i)^n$$

where: i = nominal, monthly or annual interest rate
n = number of months or years between the time when a loan is granted and the time when the owner begins to pay money back, which can be up to 6 months after start of commercial operation

In the next time period, a different amount of money is borrowed (possibly at a different nominal interest rate (i')) and the multiplying factor is now $(1 + i')^{n-1}$. This procedure is repeated for all subsequent time periods, including the last disbursement of the loan, which usually occurs before the commercial operation of the plant. The result is the IDC, which can also be calculated from:

$$\text{IDC} = \sum_{t=T_B}^{T_O} C_{t,e}[(1+i_t)^{T_O-t} - 1] \tag{12}$$

where: $C_{t,e}$ = escalated cost component
i_t = nominal interest rate (t = time of payment)
T_B = bid reference date
T_O = date when the owner starts to repay the loan.

T_O may be the commercial operating date, or up to six months later (see Fig. 10). This figure shows the cumulative values of the cash flow streams during the

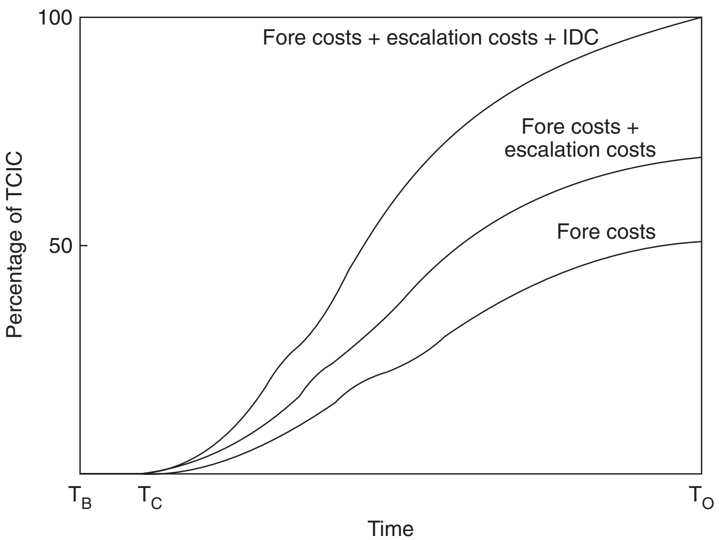

FIG. 10. Cumulative values of cash flow streams. T_B: bid reference date; T_C: start of construction; T_O: start of commercial operation.

project time for the base costs, the base costs including escalation, and the base costs including escalation and interest during construction.

The escalated cost component may be expressed as:

$$C_{t,e} = C_t (1 + e_t)^{t-T_B} \quad (13)$$

where: C_t = unescalated cost component at time t
e_t = annual nominal escalation rate at time t.

In some cases, the interest rate is not known when the evaluation is performed, because the financing offer includes a loan (a commercial bank loan) specifying a margin or a spread over a base rate (commercial interest reference rate (CIRR) or LIBOR). In such cases, a forecast of the base rate must be made for the calculation of the IDC and for subsequent bid evaluation purposes.

The importance of the IDC and the large variability in capital markets in recent years make it necessary to perform a sensitivity analysis on this parameter.

5.4.4. Project time and construction schedule

For an NPP, it is necessary to establish a work plan with time estimates. The total project time could be split into the following project phases:

- Pre-project phase;
- Bidding, bid evaluation and contracting;
- Construction;
- Commissioning.

The pre-project phase covers activities for which the owner is responsible. An A/E may assist the owner in organizing the responsibilities of the various entities involved. The pre-project phase may include:

- Concept elaboration for the entire project;
- Site plan, including site data;
- Selection of the type of NPP and its size;
- Concept plans (general layout);
- Loading data for structures (static and dynamic);
- Weight of main components;
- Preliminary construction licence request;
- Collection of BIS data;
- Selection of type of contract;
- Cost estimates;

- Staff recruitment;
- Infrastructure investigation, including local industry;
- Qualification of bidders;
- Preparation of the BIS, which facilitates the invitation of bids;
- Planning of nuclear fuel procurement.

The next phase for bidding and bid evaluation incorporates all of the steps necessary to select the best bidder. Once the best bidder is selected, contract negotiations will have to be conducted up to the point of contract signature. After reaching the effective date stipulated in the contract, construction work starts at the site. The construction period and commissioning, up to 'hand over' of the plant to the owner, can be from five to six years depending on the contract approach chosen.

The total project time may be as long as eight to ten years. Many investments have to be committed by the owner with local as well as foreign entities. Shortcomings in any of the mentioned areas have to be identified as soon as possible in order to minimize risk and keep financial losses low. Some areas incorporating certain risks are:

- Readiness of site, missing site data;
- Deficiencies in the local infrastructure;
- Insufficient number of qualified staff in the owner's organization, in the local industry and/or among the licensing authorities;
- Principal decisions are pending, i.e. type of plant, size of plant, single or multiple units, type of contract;
- Lack of finance for the owner's scope of supply and services;
- Missing important engineering documents and BIS documents;
- Missing grid expansion planning or energy demand forecasts;
- Insufficient licensing documents;
- Failure to obtain an import licence.

The individual working steps of a project plan have to be frequently checked and updated, starting as early in the project as possible in order to prevent conflicts and minimize risks which result in time delays. The scheduling of some activities may need to be shifted during project performance to prevent them from becoming activities on the critical path. As far as applicable, planning and/or feasibility studies may recommend modifications in the actual working plan. A most difficult situation may arise if some of the key components or special engineering work is delayed. If the owner is not informed sufficiently early in the project about potential delivery delays, the consequences will be the responsibility of the supplier. In the case where the owner is not able to complete some activities in time, the owner is held responsible and will have to bear the consequences. The greater the number of organizations involved in a project, the higher the risk of delays and additional expenditures. Each party individually, and all parties collectively, must fulfil the duties that they have agreed to in the contract. The risk of encountering difficulties is part of normal project development, but should be minimized as far as possible.

The realistic nature of the project schedule offered and the interaction between suppliers must be investigated with regard to possible schedule and cost consequences. In the bid evaluation process, expected risks should be noted and related contingencies should be incorporated in the estimated plant costs.

5.4.5. Economic life

The design life of a system, structure or component is the time period for which it is designed to be operable within sufficient safety margins. The main systems, structures and components of modern NPPs are designed for 40–60 or more years, which is also taken as the design life of the plant. As regards lifetime, the critical component in the NPP is the reactor pressure vessel. Pressure vessels for current NPPs are designed for about 40 years, while those for the advanced plants are designed for about 60 years.

The economic life is defined as the time period extending up to the point at which the plant should be shut down because of its excessive costs or reduced profits. The economic life of an NPP is usually assumed to be shorter than the design life. One reason for this is that after a number of years the cost of continued operation may rise substantially, e.g. when the plant is refurbished (see Section 5.6.1). The economic life is usually assumed to be from 25–40 years for evaluation purposes, although this range is somewhat arbitrary.

It should be understood that in the case of advanced NPPs which have a design life of 60 years, provision may need to be made for the exchange of major components, excluding the reactor vessel.

5.4.6. Currency exchange rates

Costs for an NPP project will arise in different currencies, but for comparing the final results, all costs should be expressed in one monetary unit. From the viewpoint of the national economy, expenditures in the local currency are generally preferable to expenditures in foreign currencies. The most important reasons for this preference are the related beneficial impacts on local industry development, employment, trade balance and recycling of local taxes.

Currency exchange rates are used to convert the import currencies in the offered bids to one currency at the reference date. Loans, such as export credit loans, are generally offered by bidders and/or banks and have to be integrated into the economic evaluation. Loans are expressed in specific currencies and must be evaluated in these currencies. This implies that, in the process of economic evaluation, conversion of all bids into a single currency can not be done before a schedule of all expenses (including the construction period and the payback period) has been computed for each bid.

A major difficulty in the conversion of future costs in several currencies into the reference currency is that the future exchange rates are not known. One way to overcome this difficulty is to calculate the PW in each currency separately, using the same reference date and the same real discount rate. The PWs are then converted into the reference currency, using the exchange rates valid at the reference date.

The bid reference date can be used as a basis for the exchange rate conversion coefficients. The values of the exchange rates should be obtained from official national banks, official publications, or other authoritative sources.

Since the economic evaluation will be carried out in current monetary terms, nominal discount rates will be used for calculating the PW in the different currencies. These nominal discount rates should be based on the same real discount rate d_r (set by the owner and common to all currencies) and on the projected inflation rates of the currencies:

$$1 + d_{nx} = (1 + d_r)\,(1 + e_{ix}) \tag{14}$$

where: d_{nx} = nominal discount rate of currency 'x'
d_r = real discount rate
e_{ix} = inflation rate of currency 'x'

The PW of all costs is then calculated from:

$$\sum \mathrm{PW(C)} = \sum_{t=T_B}^{T_E} \frac{C_{tA}}{(1+d_{nA})^{t-T_B}} + E_{A/B} \sum \frac{C_{tB}}{(1+d_{nB})^{t-T_B}} + E_{A/C} \sum \frac{C_{tC}}{(1+d_{nC})^{t-T_B}} + \ldots \tag{15}$$

where: C_{tA} = costs at time t in currency A
C_{tB} = costs at time t in currency B, etc.
$E_{A/B}$ = exchange rate of currencies A and B, etc.
A = reference currency

This method of converting all costs into the reference currency is recommended. An alternative method, based on projecting future exchange rates, is described in Appendix I.

5.5. TREATMENT OF UNCERTAINTIES

The term risk, as used in connection with physical, technical or commercial uncertainties, implies a quantitative combination of the probability of an event occurring and the severity of that event. Risk assessment is the process of estimating the probabilities and consequences of events and of establishing the accuracy of these estimates. Data and information on previous events and their consequences are used to extrapolate and forecast the probabilities of different consequences in the future.

The risks associated with an NPP project may be divided into the following areas: technical, licences, materials, qualified manufacturing staff, contractual and commercial (including financing). The risks apply to all the partners involved in a project, especially to the owner and the main suppliers.

As already outlined in Section 4, the turnkey approach implies the smallest risk to the owner, but with an increasing application of package contracts the risk increasingly moves from the main suppliers to the owner. Examples of these risks and possible countermeasures are outlined in the following paragraphs.

5.5.1. Technical area

For the NPP site, many measurements, statistics and investigations will have been generated and made available to the bidders, but uncertainties may still remain in such areas as:

- Climatic conditions.
- Geotechnical characteristics of the site, including subsoil conditions and groundwater sources, etc.
- Cooling water temperature profile and quantities of water available.
- Data reliability regarding seismic events and natural disasters.
- Transport routes for heavy equipment via sea, railways, roads and bridges (restrictions in weight and dimensions).
- Non-availability of infrastructure in time to conform to the project schedule.

5.5.2. Licences

Risks may result from the licensing requirements in the owner's or the supplier's country. To minimize these risks for the owner and for the suppliers, the licensing procedure has to be agreed upon in the contract:

- Licensing requirements for an advanced reactor may only be issued after the functional demonstration of new safety features, including test results.

- New codes and standards may lead to modifications in the design of components, systems or structures. The applicable codes and standards and their effective dates have to be fixed and amended in the contract.
- An export licence may not be granted by the supplier's government for certain sensitive equipment or for the fuel (enriched material).

Licence preparations have to be made together with the NSG and the export licence authorities in the exporting country.

5.5.3. Materials

For NPPs, a number of materials are qualified and licensed in the country of origin. In the case of national supply, these materials may not be available and experience with similar materials may not exist. This situation leads to uncertainties and extended project time. Therefore, appropriate alternatives have to be selected sufficiently far in advance.

5.5.4. Qualified manufacturing staff

In the area of national supplies, lack of experience with quality assurance and quality control in the construction of NPPs and in the processes used for manufacturing reactor equipment creates great uncertainties. These uncertainties may be resolved by establishing joint ventures among local and foreign manufacturers. These efforts imply extra expenditure.

5.5.5. Contractual and commercial uncertainties

Section 3.3 includes an outline of a contract for a turnkey NPP. The outline includes a wide spectrum and variety of items which may become subject to uncertainties in NPP projects. The number of uncertainties will drastically increase in the case of split package and multiple package contracts. Since the majority of contracts will be very dissimilar, even if similar components are contracted for, each contract has to be analysed on the probability and potential of its uncertainties. The uncertainties which may occur during plant construction and operation have to be evaluated and, as far as possible, covered by insurance:

- During manufacture and assembly of components at manufacturing facilities,
- During transport between workshop and site,
- During storage of components and their assembly in the power station,
- During commissioning and test run,
- During operation.

Some of these risks are covered by insurance in areas that are the manufacturer's responsibility, while others are insured in areas that are the owner's responsibility. The volume of insurance needed depends on the capability of the contractors and the availability of respective insurance companies ready to insure against such risks.

The following additional uncertainties have to be assessed as regards their impact on the time schedule, extra costs and extra financing. These uncertainties can be quantitatively evaluated and added to the plant costs in the form of contingencies. The owner may include specific limits in the contract for covering uncertainties. A general rule for handling uncertainties does not exist. The solutions for reconciling such events have to be agreed upon among the partners before they occur.

5.5.6. Guarantees and warranties

There may be risks in using guarantees and warranties. The owner should be aware that the greater the number of suppliers involved in a project, the greater the difficulties will be in defining appropriate warranty payments. The malfunction of a component may be due to faulty systems and components delivered by other suppliers. Regarding warranties (i.e. for load factor or fuel burnup), the supplier may be quite ready to pay a penalty in case the warranties are not fulfilled. The costs to the owner, in terms of increased production costs and replacement costs, however, may be much higher than the penalty amount.

5.5.7. Financing

Financing is an area which is susceptible to a number of risks. The owner carries the ultimate risk of the entire financing package for the project. The owner has to pay actual cash, including local costs and interests, and has to bear the consequences of escalation. The owner and the supplier together have to seek financing in such a manner that the contractual payments are met. Financing must be arranged and established with great care in order to avoid problems during project mobilization and implementation.

In the current economic climate, the planning of projects in many areas of corporate activity has to deal with an uncertain and to some extent unpredictable future. Nevertheless, techniques that can help to quantify uncertainty do exist. The process of risk analysis may well reveal that variables thought to be of major importance are relatively insignificant in the light of other factors and thus have little influence on the overall outcome.

5.6. SPECIAL SITUATIONS

5.6.1. Contracts for repair, refurbishment, upgrading and life extension

As outlined in Section 5.4.5, an NPP is designed for a 40–60 year technical lifetime. During this operating period, many active components (pumps, valves, chemical equipment and I&C equipment, including the reactor protection system) have to be replaced with new equipment. With respect to the refurbishment or upgrading of already operating plants, a very detailed scope of supply and services has to be specified as the basis for the BIS. In the case of major equipment and/or systems, a complete BIS should be prepared and organized in the form of a contract, as outlined in Section 3.

For the engineering work, the current design basis should be outlined. In addition, the former main contractor, being very familiar with the design requirements of the plant, should be contacted by the owner for assistance. This company may support the owner in establishing the BIS. The engineering work, licensing documentation and other technical details necessary for the planning and execution of such work should be incorporated in the BIS to enable the owner to receive competitive bids.

The reason for such work could be the publication of new safety requirements, age related deterioration of components and systems, or the technical state of the art of various systems and components.

Major refurbishment and upgrade undertakings include:

- Exchange of the steam generators, if applicable;
- Exchange of the primary piping;
- Replacement of the complete I&C system, including the reactor protection system and part of the main control room;
- Implementation of new safety systems, e.g. an emergency feed system;
- Modification of the complete turbine rotor;
- Upgrading of the turbine with the aim of achieving higher plant output and improved plant efficiency using the existing design margins.

Work so important that it includes modification of several plant areas normally requires a new operating licence, especially if an increase in power output is involved. These measures may lead to an extended operating lifetime and to sustained, safe, reliable and low cost electricity/heat generation.

The execution of such major refurbishment or upgrading measures requires extended outages and must be carefully assessed and planned before the decision for implementation is made. The evaluation procedure for implementing such measures must consider economic as well as technical aspects.

The costs of continued plant operation include the following items:

- Personnel costs;
- Retraining costs;
- Maintenance and repairs, including the exchange of wear parts;
- Reloads of fuel assemblies;
- Debt service for past capital expenditures;
- Allowance for decommissioning;
- In-service inspection costs;
- Appraisal and licensing costs;
- Quality assurance.

In the case of plant refurbishment/upgrading there will be additional costs covering:

- Planning, layout and engineering;
- Additional personnel costs;
- Preparation of a BIS;
- Quality assurance measures;
- Bid evaluation and contract placement;
- Placement of orders for hardware (components, I&C, piping, etc.);
- Preparation of licensing documentation (final safety analysis report, topical reports);
- Request for new licences;
- Dismantlement of existing equipment and preparation of current plant for the installation of new equipment;
- Erection and commissioning and trial test run;
- Financing;
- Replacement electricity/heat during the extended outage (if applicable).

In the case of plant shutdown, there will be costs in respect of:

- Decommissioning and waste management/disposal,
- Debt service for past capital expenditures,
- Electricity/heat replacement from the plant shutdown date.

In comparing the various options, it is useful to compare only cost differences and to disregard costs which are identical for each alternative (in particular the debt service for past capital expenditures). In determining the differential costs of plant upgrading, only the incremental costs incurred for upgrading and continued operation will be accounted for, and these will be compared with the costs of early plant shutdown and energy replacement.

For continued economic operation, it is necessary that the added revenue generated by the upgrade exceeds the differential costs of the upgrade by a margin sufficient to cover economic risk. The differential costs include principally routine O&M costs, fuel cycle costs and future capital expenditures. The differential costs also include the net cost of replacement power during the extended outage.

The comparison of the various options must include a comparison of the costs of preparing the current plant to accept the new equipment, which may vary between vendors. An important subject is the time schedule to keep the outage time short. The preparatory work and the final implementation work for the new equipment can be performed in several steps. As far as possible, this investigation should be ready in advance, before placing the new contract. These refurbishment or upgrading works can be applied to a turnkey contract as well as to a split package contract. The kind of contract depends on the experience and capability of the plant staff and the staff at the headquarters of the owner.

The economic viability of such efforts must be established and analysed. The alternatives offered have to be compared with each other. In some countries, the decision to install new equipment may not be based solely on economics but may also be motivated for political reasons. For example, if a new NPP were not to be licensed, but an increase in electricity consumption is dictated by local consumers, the utility may have to refurbish an existing NPP in order to meet the demand, even if the differential costs of the refurbishment exceed the cost of plant shutdown and energy replacement.

Several risks have to be taken into account to prevent economic losses. Various risks need to be assessed, such as:

- Adaptability of existing technology to support a higher plant output with new equipment,
- Life extension,
- Economic risk related to electricity generation cost,
- Contractual risks,
- Operational risks,
- Financing risks.

The main economic risk relates to final plant shutdown which, for political or other reasons, occurs prior to the end of the plant's technical life as a result of the change from revenue production (remaining generation value) to financial obligation (the investment costs for a new plant, including licensing). If the additional costs necessary for refurbishment are too high, the plant's economic viability might be degraded, which could lead to the decision to shut down the plant. This risk increases with the length of the operative lifetime, since the shorter the remaining lifetime, the higher the probability that the plant will be taken out of service.

The method for calculating the various alternatives will basically be the same as that explained in Section 5.3. Some additional considerations are summarized below.

The differential cost in the year(s) with improvement activities can be calculated from the following expression:

$$C_a = C_{om} + C_f + C_l + C_i + T_{out} \times P \times c_{re} \tag{16}$$

where: C_a = differential cost
C_{om} = O&M cost
C_f = fuel cost
C_l = licensing costs for continued operation
C_i = cost of plant improvement
T_{out} = outage time (hours)
P = average capacity required to compensate for plant outage (MW(e))
c_{re} = average price of replacement electricity (per MW·h).

In other years, the differential cost will simply be:

$$C_a = C_{om} + C_f \tag{17}$$

Other costs, such as the plant decommissioning costs, may be the same for the alternatives considered but may differ in their time of occurrence. This, as well as other timing effects of the expenditures and income, will be evaluated by means of a cash flow analysis. Since the costs are unevenly distributed over time, their time dependent value is considered by way of discounting.

Commonly used yardsticks for judging the outcome of the economic evaluation are:

- Marginal cost of continued operation in terms of levelized generation cost,
- Net present worth of the improvement project,
- Internal rate of return of the improvement costs.

The recommended method for the economic evaluation of differential costs uses the marginal costs of continued operation in terms of levelized generation costs, which can be calculated from the discounted values of costs and electricity as follows:

$$C_m = \frac{\sum_{t=0}^{L} \frac{C_{a_t} + C_{o_t}}{(1+d)^t}}{\sum_{t=0}^{L} \frac{E_t}{(1+d)^t}} \tag{18}$$

where: C_m = marginal cost of continued operation (per MW·h)
C_{a_t} = differential cost in year t
C_{o_t} = other costs in year t
E_t = electricity generated in year t (MW·h)
d = discount rate
L = study period (years).

The study period should include the expected plant life remaining after improvement. The marginal costs of continued operation after improvement will then be compared with the marginal costs of other options in order to determine the economically preferable solution. The comparison may be performed on a plant level or system level and based on current or constant monetary value. When comparing the option of early plant shutdown and construction of a new plant, the remaining value (salvage value) of the new plant at the end of the study period (L) must be deducted from the costs of the option. The salvage value may be calculated by straight line depreciation or by another method preferred by the utility. A discussion of two other methods for the economic evaluation of differential costs is provided in Appendix I.

5.6.2. Dual purpose (co-generation) plants

Dual purpose plants generate both electricity and heat, which may be used for industrial processes, district heating or seawater desalination. The evaluation of dual purpose plants is more complex than for electricity only plants. The preferred method for the economic evaluation of co-generation plants is the power credit method. This is based on the concept that the electricity equivalent of steam supply (electricity that could have been generated by the steam supplied to the heat consumer) and/or the electricity provided to the seawater desalination plant or other bulk consumer could have been sold to the grid, and that this loss in revenues should be charged to the heat or potable water cost (power credit). The power credit is calculated by multiplying the reduction in electrical output by the unit electricity generation cost of an equivalent single purpose power plant. Applying the power credit method, the potable water produced is credited with all of the economic benefits associated with co-production.

Other methods for allocating the costs of co-production to the products, i.e. electricity and heat or potable water, are described in two IAEA technical documents.[1]

5.6.3. Privatization of NPPs

In many countries around the world, nuclear power is under the control of, and owned by, the respective governments, although the NPPs are integrated into the entire energy system. The grid and the local electricity distribution systems are also government controlled in many countries. In these countries, the electricity tariffs are often not based on economic calculations, but are fixed by the government.

Nowadays, these energy production and distribution facilities have become targets for privatization. If private entities were to take over the current installations, they would be held responsible for all questions and problems related to the installation, maintenance and operation of the plant(s). Their responsibilities would include fuel cycle activities, waste storage of operational radioactive waste, decommissioning and disposal or storage of the spent fuel. The achievement of privatization will be a very difficult and comprehensive undertaking, requiring careful planning to transfer the responsibility from the government to a private entity. In particular, the cost situation for plants in operation, under construction, or being planned will have to be assessed in detail and related precautions will have to be implemented.

Privatization can not be the subject of bid evaluation, because a foreign bidder can not resolve the kinds of questions involved. However, some points may be discussed jointly in order to find reasonable solutions in the various fields. The following list should be understood as a reminder of the kinds of question that need to be resolved:

- The transfer of ownership from the government to a private entity has to be agreed upon and stipulated in a contract document.
- The future operation of the respective NPP(s) has to correspond with the electrical system expansion planning, the plant(s)' economic viability and the deployment of future plants.

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[1] INTERNATIONAL ATOMIC ENERGY AGENCY, Technical and Economic Evaluation of Potable Water Production Through Desalination of Seawater by Using Nuclear Energy and Other Means, IAEA-TECDOC-666, Vienna (1992).

INTERNATIONAL ATOMIC ENERGY AGENCY, Thermodynamic and Economic Evaluation of Co-production Plants for Electricity and Potable Water, IAEA-TECDOC-942, Vienna (1997).

- The electricity tariffs must be established in accordance with economic considerations. Free access to the grid and the unfettered connection of the consumers must be granted.
- The various licences for construction and operation have to be transferred from the government to the private entity and issued in due time.
- The operating and maintenance staff have to be recruited, qualified and trained (before and during operation) by the private entity.
- The nuclear fuel cycle has to be incorporated into the privatization programme, including front end and back end activities.
- The central storage facilities for storing radioactive waste from operation and spent fuel have to be planned in close co-operation with the government.
- The government is obliged to keep its responsibility for nuclear liability.
- Decommissioning costs have to be planned for the plant at the end of its technical life.
- An effort to gain public acceptance of nuclear energy under the responsibility of a private entity has to be organized (information centre at site, lectures and presentations at universities and other national organizations, preparation of written materials, contacts with the public media (press and television)).
- For fulfilment of the privatization process, sufficient time and overlapping periods for relinquishing and accepting authority in the various fields of interest should be foreseen.

The privatization of an NPP(s) has a tremendous impact on the socioeconomic structure of the respective country and must be assessed in connection with other privatization activities in that country. Local industry working under private responsibility will accrue benefits that will spread throughout the country's economy.

6. SOURCES OF FINANCING, FINANCING PROPOSALS AND ASPECTS OF THE ECONOMIC EVALUATION OF FINANCING PROPOSALS

6.1. INTRODUCTION

The incorporation of an NPP into an existing grid is a great undertaking which requires organizational skills, technical expertise and qualified personnel, as well as a comprehensive financial plan. In addition to the technical and commercial specifications, financing requirements (if any) are usually specified in the same BIS. The quality of the financing proposals and their appropriateness for a particular owner are inevitably a function of the extent to which the financial requirements are specified in the BIS. Before issuing the BIS, the owner has to clearly establish its financing requirement and preference in terms of currency, interest rates (fixed or floating rates), and the total amount of financing needed in the currency of the owner's country and/or in foreign currencies. The percentages of the different financing packages have to be indicated in accordance with the financing capability of the owners. Likewise, the types of security desired need to be specified. In many BIS, such information is missing, but it is essential to describe the framework in which the expected proposals will cover the owner's requirements and needs. In some BIS, only the financing of the imported part is requested, while others also ask for the financing of local supplies in local currencies. Failure to request a complete spectrum of financing has led to difficulties for many developing countries.

The electric utilities with limited access to internal or domestic financing resources want to pay as little as possible during plant construction. This implies that 100% foreign financing is to be provided to cover base construction costs, escalation during construction and IDC, capitalized until the start of commercial operation. In this regard, the period before commencement of repayment of debt (i.e. the grace period) has to be minimized so as to reduce the capitalized IDC. If a specific period stipulated in the contract (e.g. from contract effective date to start of commercial operation) or the original duration planned for the construction period is extended, the repayment of debt will have to commence earlier (before the power plant generates revenue). In this event, rescheduling of all or parts of the loans has to be negotiated.

The scopes of supply from local and foreign sources have to be defined in the BIS as fully as possible, or they have to be determined on the basis of a separate appraisal that is input into the bid evaluation process. The local capability for the manufacturing of components and supply of materials in the owner's country has to be assessed. This underscores the difficulties facing developing countries in obtaining the large sums of money required to cover local expenditures through their own banking systems or through government grants. No more than 85% of the value of the foreign capital can be granted by the export credit institutions of exporting countries. This restriction comes from the Sector Understanding on Export Credits for Nuclear Power Plants, in the Arrangement of Guidelines for Officially Supported Export Credit promulgated by the Organisation for Economic Co-operation and Development (OECD). The balance must be financed through commercial loans. Since a commercial bank is likely to limit its participation in the financing of an NPP, the complete project financing has to be syndicated between a number of banks or financial entities.

The traditional financing approach is mainly based on a double buyer credit: one part to be covered by a loan from the export credit agency of the exporting country and another part to be covered by loans from commercial banks.

Leasing, countertrade, joint ventures, multicountry financing and co-financing are alternative approaches which may be utilized. Each approach needs careful analysis by the lenders, suppliers and owner(s). In fact, it is not only the large amount of money required which makes financing of NPPs difficult, the creditworthiness of the owner's country as estimated by the various lending organizations is also an important factor.

6.2. FINANCING PLAN

A financing plan includes the collection of relevant data (as a function of time) on project related factors. These comprise the total capital investment, the nuclear fuel cycle costs with front end and back end components, the respective local and foreign portions, the establishment of debt/equity targets and the assessment of potential financing sources. Additionally, there needs to be a definition or estimation of a number of key economic and performance parameters.

The ease with which the financing package may be arranged will depend on the level of financial resources that are available to the owner. The resources may take the form of owner's equity, subordinated loans or appropriation from the national budget. In general, the World Bank regards that as a rule the owner's equity should be in the range of 20–30% for the power sector. The International Finance Corporation (IFC), which belongs to the World Bank group as the private ownership institution of the International Monetary Fund, usually requires a minimum owner's equity of 30%.

It should be noted that the amount of equity which the financial institutions require in a project is essentially a function of the debt service coverage ratio. Depending on their perception of the project's risk, financial institutions will usually require debt coverage ratios of 1.3 or higher. For a given projected cash flow, this ratio effectively determines the amount of equity required.

Since the investor providing the equity usually requires a higher return on the investment than the cost of debt, equity financing is the most expensive form of capital resource. This applies especially in the innovative off balance sheet financing models. In the traditional balance sheet financing, the required return on equity is lower because the utility or government authority usually has a better understanding of local risks and can manage them more effectively.

The above concepts drive the amount of equity in opposite directions. Debt coverage ratio requirements increase equity ratio, while a desire for minimum financial cost and increased return on investment decrease equity ratio. Therefore, the optimal equity ratio is a matter for negotiation with the financiers. Financial institutions expect project owners to take an increasing share of the risks as the evidence of a commitment to ensure the successful implementation of the project. Thus, the lenders usually require a minimum of 15% of the total initial investment to be covered by the owner's resources.

Another basic principle in financial planning is that local costs should be covered by domestic funds. This is a very strict requirement in many countries, and its complexity is often underestimated. Experience shows that raising enough money for local cost financing from foreign sources, local capital markets or government budgets has often proved to be impossible and has been the main reason for delays in project implementation. Commitment by the local authorities to guarantee funds for the local funding portion and secure its continuity and availability in a timely manner is one of the major factors in ensuring a successful project and the meeting of budget constraints.

Covering the gap in financing local costs by using foreign exchange funding from abroad proves to be problematic. To avoid straining the foreign exchange reserve balance of a country, with all the associated negative impacts, local costs should in principle be financed in local currency from sources within the host country itself. This is especially necessary as power plants are almost always operated for domestic use only, thus generating cash flow only in local currency.

Sources of funds in the local currency for investment in a public utility power project could be from government loans, issue of common stock, or retained earnings from the owner's operating organization/utility. The utility's funds could either be from equity or from accumulated earnings set aside especially for such a planned investment. These sources could be supplemented by credits raised in the domestic capital market. Difficulties in financing local costs arise from shortages of government funds and constraints in local capital markets. The development of a well functioning domestic capital market is particularly important for organizing local financing. Since foreign currency financing of local costs increases the debt burden and carries a foreign exchange risk, it is vital for successful project implementation that sufficient local financing be secured.

In developing countries, the financial capability of the utilities is largely constrained owing to insufficient internal cash flow generation. This results from inappropriate electricity tariffs which sometimes do not even cover operating expenses and debt service. Therefore, the role of the government in establishing reasonable electricity tariffs must be emphasized. Only in this way will the project executing agency achieve the sound financial strength needed to finance investments from its own resources or to be perceived by the lenders as being creditworthy.

Once the financing of the local financing portion is settled, there are various possibilities for approaching international finance markets. A relatively large portion (60–85%) of the total investment cost of a nuclear power project, especially in a developing country, is usually required in foreign currency because the high technology equipment and services must usually be imported. This part of the investment must be financed through export credit agencies, multilateral development institutions, bilateral financing sources, international commercial loans and/or bond issue. However, the product — electricity — and the revenue from it will be denominated in local currency. Consequently, entities which have invested in the project in foreign currencies will require a transfer guarantee from the host government that their original investment, together with interest or dividends, can be repatriated in a convertible currency.

6.3. FINANCING SOURCES

Financing of a major nuclear power project for developing countries is typically done through a combination of export credits, commercial loans and owner's resources.

For a traditional financing arrangement in the construction of an NPP, the principal sources of local financing are:

- Owner's resources
- Domestic bonds
- Loans from local banks
- Credits from public entities.

For the foreign scope, the principal financing sources are:

- Export credit agencies
- Commercial banks
- International development agencies
- International bond markets.

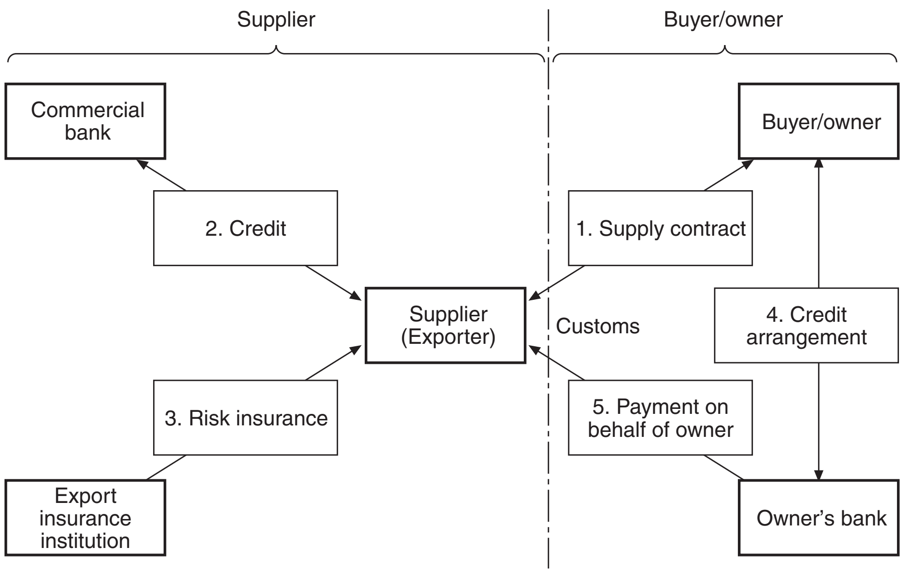
In the event that the above financing sources are insufficient to cover the projected cost of the nuclear power project, other financing mechanisms or arrangements must be considered. Some of these arrangements are:

- Project financing
- Multicountry financing
- Multilateral countertrade
- Joint ventures
- Leasing.

Some of these financing sources and the types of loans available are discussed below.

6.3.1. Export credit

An export credit arises whenever a foreign buyer of exported goods and services is allowed to defer payment. Export credits are generally divided into short term (usually under two years), medium term (usually two to five years) and long term (usually over five years). They may take the form of 'supplier credits', extended by the exporter, or 'buyer credits', where the exporter's bank or other financial institution lends to the buyer. Export credit agencies may give official support to both types of credit. This official support may be limited to 'pure cover', which means that insurance or guarantees may be given to exporters or lending institutions without financing support. Figures 11 and 12 illustrate the relationship of the key players in supplier credits and buyer credits.

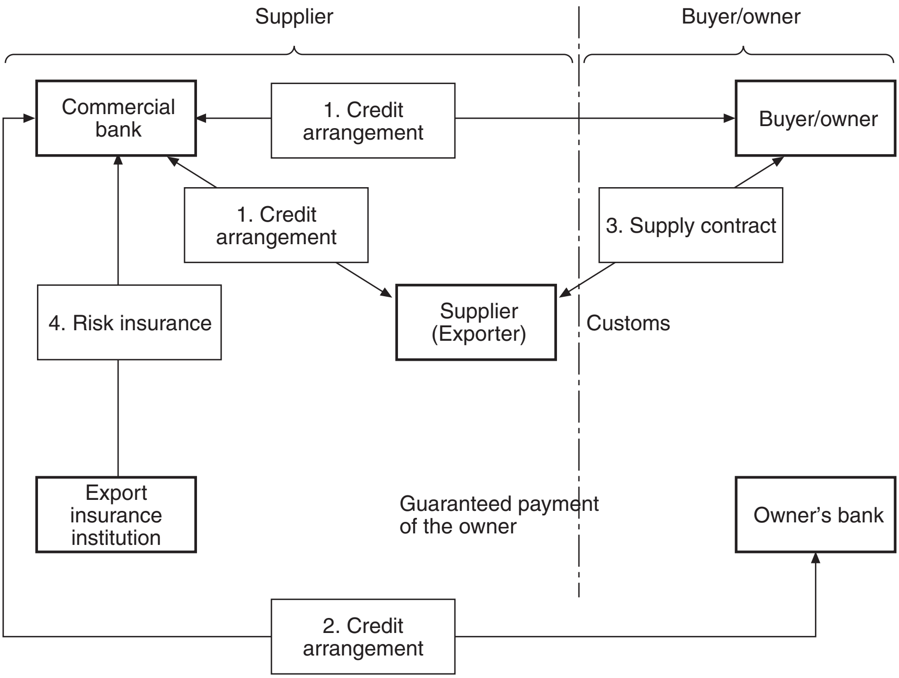


1. Supplier and buyer/owner agree on supply contract.
2. Supplier applies to commercial bank(s) for credit(s), from which the contracted supplies are paid.
3. Supplier's credit is insured by a credit insurance institution supported by the exporting country against political and economic risks.
4. The buyer/owner has a credit arrangement with a national bank.
5. The national bank pays the supplier's invoices on behalf of the buyer/owner.

FIG. 11. Supplier credits arrangement.

Alternatively, the export financing may be given in the form of 'financing support', which is defined as including direct credits, refinancing and all forms of interest subsidy. Official financial support may or may not be given in conjunction with the basic guarantee or insurance facility. Currently, there are 22 OECD member countries having membership in the Group on Export Credits and Credit Guarantees (ECG) of the OECD Trade Committee.

The ECG members also participate in the Arrangement on Guidelines for Officially Supported Export Credits, which came into being in April 1978. This is an arrangement that was accepted directly by its participants and developed within the framework of the OECD. It replaced a less elaborate understanding that had been in effect among a limited number of OECD member countries since early 1976.



1. The buyer/owner assumes responsibility for the credit arrangement by direct contact with the bank of the exporter.
2. Loan agreement can also be between the buyer/owner's bank and the exporter's bank in favour of the exporter.
3. Progress payments are agreed between the exporter and the buyer/owner in accordance with the 'milestone' events reached during construction.
4. Credit insurance institution underwrites the risk insurance. Insurance premium borne by buyer/owner.

FIG. 12. Buyer credits arrangement.

The main purpose of the Arrangement is to provide the institutional framework for an orderly export credit market and thus prevent an export credit race. In a credit race, exporting countries would compete on the basis of offering the most favourable financing terms rather than on the basis of offering the highest quality and best service for the lowest price. The Arrangement does not cover the conditions or terms of insurance or guarantees. It only covers the conditions or terms of the export credits that benefit from such insurance and guarantees. As such, it deals with actions and policies of official export credit and insurance agencies. It sets limits on the terms and conditions for export credits with a duration of two years or more that are officially supported (i.e. those that are insured, guaranteed, extended, refinanced or subsidized by or through export credit agencies). Within these limits, certain 'derogation' from the rules and some 'deviation' from what is considered normal practice are possible. Notification of these must be made to all of the other Participants in the Arrangement, which can then 'match' the deviation or derogation.

Several sector understandings, which set special terms for the sectors concerned, have been developed. Provisions in the Sector Understanding on Export Credits for Nuclear Power Plants are described in the following paragraphs.

6.3.1.1. Creditworthiness

The creditworthiness of the importing country and the sponsors is a key issue when the financing institutions and lenders look at the loan requests. Doubts in this field can be a very serious obstacle to nuclear project financing. It is unlikely that any scheme could be found to finance nuclear power projects in countries with very poor creditworthiness, especially in view of the large investment cost of NPPs. Only countries with acceptable credit ratings would qualify for bank loans and other credits for financing such a project. The development of sound economic policies, a good debt management record and project risk sharing would all help to improve the credit ratings of the country concerned.

Besides the loan availability, the interest rate also depends on the creditworthiness. Therefore, maintaining a good reputation in this field is a 'must' for a country intending to implement nuclear power. International agencies rate various countries and major firms according to specific criteria from time to time, especially when major changes influencing the national economy have taken place. Moody's Investor Service, IBCA and Standard & Poor's are the best known agencies and their ratings are keenly observed among governments, lenders and investors. One should acknowledge that such ratings of a country or major firm form a basis on which interest rates are set.

Traditionally, export credits fund a maximum of 85% of the foreign scope of the project, with the possibility of 15% of the foreign scope to be used for financing local costs. The balance of the foreign and local costs would come from other financing sources such as commercial loans and owner's resources.

6.3.1.2. Grace period

OECD consensus rules allow for a grace period of six months beyond the construction period.

6.3.1.3. Interest rates

The minimum interest rates stipulated in the OECD Export Credit Arrangement for export credits that receive official financial support are the CIRRs for currencies being used. The CIRR for each OECD member country's currency is determined on a monthly basis, reflecting the country's long term treasury bond rates. However, in the case of NPPs, the interest rate is the special commercial interest reference rate (SCIRR). The SCIRR is the standard CIRR plus an addition of 0.75% for all currencies, except that this addition is 0.40% in the case of the Japanese yen. These are the current additions as of mid-1998 and may change over time.

Thus, the applicable interest rates for the financing of an NPP for a developing country will be confirmed at the same time that the financing arrangements for the project are agreed upon by all the parties concerned. For example, the CIRR for US dollars for the period 1998-9-15 through 1998-10-14 was 6.36%, as shown in Table V. On the other hand, the CIRR for the previous monthly period was 6.52% for long term loans (Table V). Using the CIRR rate of 6.36%, the SCIRR rate is calculated as 7.11% for US dollar loans.

The minimum interest rates on which the export credit interest rates are based vary considerably from month to month and from country to country. While the interest rates for some countries may increase from one month to another, the rates for other countries may decrease over the same period.

6.3.1.4. Method of repayment of principal

The principal of the export credits would be repaid in 30 equal semi-annual instalments, made twice yearly, following the grace period.

6.3.1.5. Method of payment of interest

The interest on the outstanding balance of the export credit principal would also be paid semi-annually.

6.3.1.6. Financing fees

The export credit agencies generally charge an exposure fee to the exporter, the level of which is country dependent. This fee is to be either added to the supplier's

TABLE V. ARRANGEMENT ON OFFICIALLY SUPPORTED EXPORT CREDITS[a]

Changes in CIRR

1) Minimum interest rates stipulated in the OECD Export Credits Arrangement for export credits that receive official financing support are the CIRRs for the currencies being used.
2) A CIRR is fixed for each currency — including the ECU — that is used by Participants in the Consensus. CIRRs are subject to change on the 15th of each month. CIRRs for the period from 1998-9-15 through 1998-10-14 are listed below
(previous period in second column):

Currency denomination		CIRR for periods (%) 1998-9-15–1998-10-14	1998-8-15–1998-9-14
Australian dollar		6.81	6.31
Austrian schilling		5.24	5.43
Belgian franc		5.45	5.78
Canadian dollar	≤ 5 years	6.56	6.32
	5 to 8.5 years	6.52	6.29
	> 8.5 years	6.58	6.33
Danish krone		5.64	5.64
Finnish markkaa		5.37	5.56
French franc		5.29	5.53
German mark		4.99	5.37
Irish punt		5.29	5.56
Italian lira		5.54	5.70
Japanese yen		2.30	2.30
Netherlands guilder	≤ 5 years	3.17	3.26
	5 to 8.5 years	4.90	5.30
	> 8.5 years	5.10	5.55
New Zealand dollar		5.60	5.95
Norwegian krone		6.99	6.34
Spanish peseta		5.29	5.51
Swedish krona		5.60	5.61
Swiss franc		3.96	4.21
UK pound		6.94	7.20
US dollar	≤ 5 years	6.24	6.47
	5 to 8.5 years	6.27	6.46
	> 8.5 years	6.36	6.52
ECU		4.97	5.19

Note: A premium of 0.2% is to be added to the CIRRs when fixing at bid. Interest rates may not be fixed for longer than 120 days.

[a] OECD News Release, Paris 1998-9-10. Monthly updates of the CIRRs can be obtained from: OECD Publications, 2 rue Andre-Pascal, 75775 Paris Cedex 16, or via the OECD's internet website at http://www.oecd.org/news_and_events/new-numbers/cirr/.

price to the client or paid directly by the borrower to the lender. In addition, there are normal administration, commitment and disbursement fees which are charged directly to the borrower. The financing fees vary considerably between the export credit agencies, reflecting the agencies' assessment of the creditworthiness of the owners' countries.

6.3.1.7. Cash payment

Borrowers (purchasers of exported goods and services) receiving officially supported export credits must self-finance cash payments for up to 15% of the export contract value at or before the contract starting point.

6.3.1.8. Local costs

Foreign financing of local costs, if any, is limited to 15% of the foreign scope of supply.

6.3.2. Commercial banks

Commercial banks are providers of short to medium term funds, with a preferred maximum loan life of ten years or less. The terms available vary and depend upon market liquidity and the banks' perception of the creditworthiness of the potential borrower.

A ten year loan with floating interest rates would typically have a two to four year grace period, followed by equal semi-annual loan repayments over the remaining loan period. The interest rates for various currencies are linked with the LIBOR, usually expressed in terms as high as four per cent above that rate, including management and commitment fees. In mid-1998, LIBOR rates were in the five to six per cent range for loans in US dollars.

If loan repayment is due to start before the scheduled completion of construction or before the scheduled start of commercial operation, the size of the surety bond required by the lender will reflect the recognition that loan repayments will come from other sources of funds available to the borrower.

Tapping the commercial market requires a careful analysis of all parameters, such as the timing of drawdowns, the maturity of the loans and repayment schedules, and the impact of currency fluctuations. Financing may come from different countries and from different financial sources, and thus careful financial management by the owner is required.

6.3.3. International development agencies

International development institutions may become an important source of long term funds. Typically, regional aspects are important. The terms and conditions of lending offered by development institutions are specific for each of the institutions. In general, the loans are agreed for a period in excess of ten years. It is important to commence discussions at an early stage to allow adequate time for review of the entire project.

6.3.4. Bond markets

Depending on the ownership structure and creditworthiness, it may be possible to issue local bonds in order to finance a portion of local costs.

6.4. FINANCING PROPOSALS

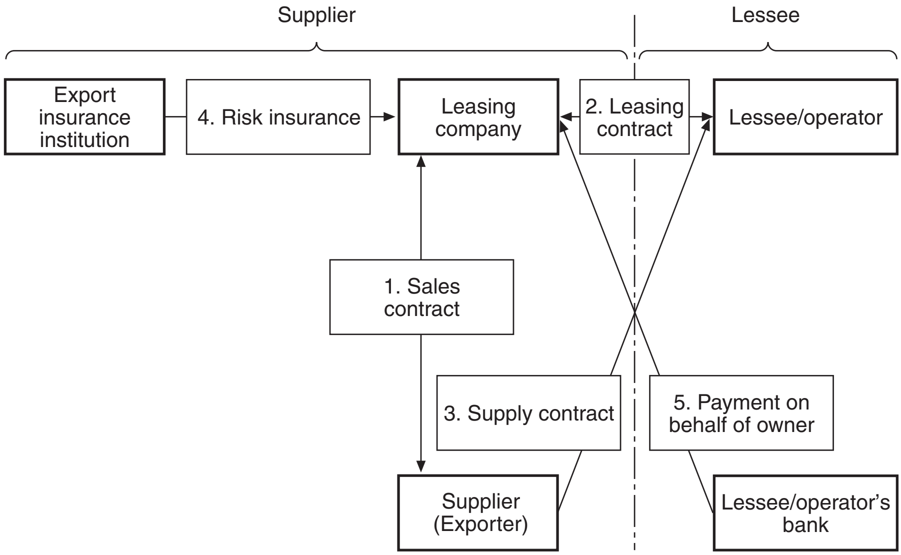
The financing proposals for an NPP owner may range from anything up to 100%. In the BIS, some owners may request that a portion of the plant price be paid for in terms of countertrade. Countertrade may involve reciprocal trade between two or more countries. For a limited scope of supply, such as removal and replacement of major components and systems in the rehabilitation of ageing plants, countertrade may be considered. The proportion of financing done through countertrade depends on the products, materials, natural resources or electricity available for compensation. Electricity supply needs a stable grid connection between the owner's and the supplier's country. It has to be realized that the need to utilize agents in countertrade arrangements leads to increases in costs. Since the sum of money available to the project will be reduced by agents' fees, additional sources of financing have to be established. Export credit institutions are generally reluctant to offer export credit financing if countertrade forms an integral part of the financing proposal.

Countertrade proposals must be analysed carefully with regard to their economic viability relative to other financing proposals available in the international or multinational market.

6.4.1. Leasing

The leasing of an NPP from a consortium of banks or from a leasing company has the advantage of excluding the initial capital investment from the assets on the owner's balance sheet and requires no change in the debt/equity ratio. This may remove any question concerning the creditworthiness of the owner or the owner's country. This model could favour the saving of taxes and customs expenditure which might have to be paid to the government of the owner's country in accordance with country specific laws and regulations. These expenditures would certainly have an impact on the total financing costs. If the leasing model leads to depreciation of the entire initial investment costs, leasing may be considered as an alternative approach. However, the viability of this approach would depend on whether banks or separate leasing companies would accept the risk related to deployment of an NPP in a developing country. Basically, the same analysis has to be performed as that briefly outlined for the BOO/BOOT models in Section 3. Figure 13 illustrates the relationship among key players in an export leasing arrangement.

In the case of pressurized heavy water power plants, the costs of the initial heavy water inventory may not be recognized as initial investment. They may be treated as part of the O&M cost and are paid back over an agreed period of time.



1. Supplier agrees on a sales contract with a leasing company.
2. The leasing company establishes a leasing contract with an importing organization, such as a utility.
3. The supplier and the utility agree on a supply contract.
4. The leasing company arranges export insurance with a government backed insurance institution.
5. The leasing company establishes the leasing fees on the basis of the supply contract, including all subsidiary costs and interests. The leasing contract may have provision for the importing organization to purchase the plant for a stipulated price on the expiration of the leasing contract.

FIG. 13. Export leasing arrangement.

6.4.2. Multilateral countertrade

As noted at the beginning of Section 6.4, countertrade is not the most effective or recommendable way of financing NPPs. The sum of money needed for the construction of an NPP is relatively high compared with other energy supply projects. In many cases, the resources of the owner's country that are available for countertrade are very limited or none existent.

Theoretically, various models of countertrade can be assumed:

- Exchange of products
- Compensation
- Counter supplies
- Purchase of products.

Assessing the various advantages and disadvantages of these models, and considering the risks and uncertainties in the countertrade financing model, their application is rather limited. Because of the lack of relevant detailed information that may be available in various countries, this approach to financing an NPP should only be considered as a last resort.

6.4.3. Joint ventures

The formation of a joint venture could be arranged between two or more partners to set up a separate entity for the express purpose of building a power plant. The joint venture would then provide energy to an energy distribution organization, possibly the local utility, which may be one of the partners. Specifically, the main contractor would not enter into a joint venture because of problems with project financing. It is strongly recommended that the local utility or the energy distribution organization becomes a partner in the joint venture, or that the joint venture takes steps to ensure access to the distribution system. The joint venture normally requires a lead partner responsible for co-ordination of the different supply packages and their interfaces. The collective and individual responsibilities of the partners in the joint venture must be negotiated and agreed upon in the partnership agreement, including the tenure of the partnership.

6.4.4. Multicountry financing

A multicountry financial scheme can be arranged with supplies and services offered by a variety of companies in different countries. In this case, the project is based on a broader financial foundation by spreading the financing risk among several countries. The international suppliers must agree on the contractual arrangement in which one lead supplier assumes leadership for project co-ordination. In this model, financing by commercial banks in connection with suppliers' financing may lead to an attractive financing package.

6.4.5. Project financing

In a project financing scheme, the government of the importing country guarantees the purchase of the electrical energy generated. The guaranteed price must cover the financing costs and the revenue of the foreign investors, which will build the plant and operate it until all debts are repaid. Thereafter, the ownership of the plant is transferred to the owner's organization.

This kind of financing of an NPP has to be checked carefully and a risk assessment has to be performed. The financial solvency of the owner's country has to be analysed carefully and provisions established in the contractual arrangements to protect the lenders against potential losses.

6.5. ASPECTS OF THE ECONOMIC EVALUATION OF FINANCING PROPOSALS

The evaluation of the financing proposals involves both a qualitative and a quantitative analysis. For the quantitative analysis, an analytical methodology should be developed with the assistance of a competent financial adviser. Important aspects of the qualitative and quantitative analyses are discussed in the following paragraphs.

6.5.1. Qualitative analysis

The qualitative analysis considers such items as the firmness and completeness of the financial offers, the security structure, the ability of the bidder's banker to give assurance for the financing, and the attractiveness of the financing terms and conditions. The following items have to be considered:

- The qualitative analysis should begin with a review of each financing offer and should determine the degree to which it complies with the financing specifications of the BIS. Each requirement of the BIS should be checked against the financing terms and the schedules offered. Particularly important are the requirements regarding the terms and percentage of financing requested and the confirmation of liability.
- Are the terms of financing appropriate to the project and do they fit the payment requirements of the contract? This question involves checking that the

availability or drawdown periods of the loans match the payment schedule based on the construction sequence of the plant.

- When does loan repayment commence? Is the repayment schedule set with reference to the start of commercial operation or to another specific date? If the repayment of the loan starts before commercial operation, refinancing may be necessary, and both the owner and the prime contractor will have to approach the financial markets again. This implies a certain risk because the financial markets may have deteriorated in the interim. The consequences have to be analysed by the owner and negotiated with the bidder with regard to improvements or changes to the financing proposal.
- The expiration date of the complete offer (plant, contract and financing) should be set far enough in the future to allow the owner to perform a detailed and comprehensive bid evaluation. As regards the financing offer, the stability or volatility of the markets is important. The validity period of the financing offer should coincide with the requirements fixed in the BIS. Deviations have to be addressed specifically and have to be justified.
- The various tools used for financing of the specified NPP have to be tailored to the BIS requirements. Consideration must be given to the precautions taken by banks and international credit institutions on long term financing because they are based on current market conditions.
- The financial proposal should provide the opportunity for the bid evaluation team to check the recommended binding conditions on specific risks. Proposals incorporating elements that are subject to speculation or other less reliable issues should be rejected.

Contractual arrangements agreed to between the prime contractor and owner are confidential business and include economic considerations, which are not appropriate subjects for analysis and discussion in an IAEA publication.

6.5.2. Quantitative analysis

Various explicit and implicit financing fees and taxes have significant impact on the total amount of financing, as do the repayment period, the type of interest (fixed, floating or a combination of both) and the rate, and the method of compounding. These cost elements together lead to a considerable increase in the amount to be financed. Of further interest are the different currencies, their respective national inflation rates, the cross exchange rates between currencies and their resultant impact on the economic viability of the project. Surety for the loans and their cost should be explained separately, including identification of the granting entity or entities which are held responsible for the total project financing.

The analysis of the rather complicated structure of financing proposals requires specific 'know-how' which can be incorporated into the bid evaluation team by hiring a financial consultant. The consultant should participate in the preparation of the BIS and assist in the development of the procedure to be used to analyse and compare the various proposals.

If financing is being developed for a limited scope of supply and services (e.g. update of current plants), then countertrade may be considered as a financing source where appropriate.

Although the influence of financial offers is quantitatively taken into account in the computation of the LDGEC, detailed analyses of the financing proposals are necessary using internationally accepted methodologies.

7. IMPLEMENTATION OF THE ECONOMIC BID EVALUATION

7.1. INTRODUCTION

The objective of this section is to discuss the implementation procedure for the economic bid evaluation. It is based on the content of Sections 3–5.

The economic bid evaluation starts with the receipt of the bids and ends with the final evaluation report. An outline of the complete bid evaluation process is illustrated in Figs 1 and 4.

For the economic comparison of the offered bids, the established evaluation group or groups should begin the assessment by comparing each bid with the BIS requirements or with a reference bid, whichever is the one deemed to be the most complete. In the implementation process, the differences among the offered bids in the scope of supply and services and in the technical aspects have to be assessed and the cost consequences evaluated in terms of economic adjustments. These adjusted costs are then added to or subtracted from the base prices to obtain the adjusted base prices. The system of accounts presented in Annex I provides a convenient checklist for identifying the systems or subsystems and services required for the evaluation of the cost adjustments. In addition, all economic parameters and all commercial and contractual terms and conditions have to be assessed and their cost consequences identified. These cost consequences are obtained from the variations among the offered bids and take the form of economic adjustments to the offered costs.

Economic adjustments are required in order to put the offered scope of supply and services of the bids on a common basis so as to make them economically comparable. A large effort, good judgement and specialized knowledge are needed for this task, especially when the offered bids are for different reactor types.

During the entire evaluation phase there should be a constant flow of communication between the evaluators and bidders, preferably in written form but also through oral discussions. The objective is to complete the information contained in the bids and clarify dubious points. To expedite a fast and efficient information flow, both the bidders and the owner must provide duly authorized representatives with adequate authority and technical qualifications.

The reasons for the rejection of bids are due mainly to non-compliance with the BIS requirements. Criteria for the elimination of bids are normally outlined in the BIS and give guidance to both parties, the bidder and the assessment team of the owner. The decision for rejecting bids should be documented in a written report. The rejected bidders should be notified and provided with a copy of the report.

The evaluation of bids must consider the type of contract selected, particularly for the multiple package approach, and the scope of supply and services specified in the BIS. It is especially important that the BOP offerings and costs are carefully analysed and accounted for in accordance with these considerations and with the IAEA account system. Offerings and costs of the NSSS, NI and CI also need to be carefully analysed. Definitions of the scopes of these items vary considerably among vendors, A/Es and utilities. Receiving bids in terms of the IAEA account system, however, leads to a common approach for all the bidders and greatly eases the analysis. Interfaces within and among the various scopes of supply and services for multiple and split packages should also be identified in accordance with the IAEA account system. The IAEA account system provides the means to harmonize major scope variations, organize BOP analysis and assist in the identification of interfaces. These capabilities justify the requirement that bids for supplies and services be made in accordance with the detailed IAEA account system. The cost consequences resulting from these analyses should be incorporated into the economic bid evaluation.

For the total plant cost and the LDEGC, the owner's costs, as well as the fuel cycle and O&M costs, must be estimated. The discounted total plant costs are then divided by the discounted energy generated over the economic life of the plant to give the LDEGC. The preferred bids may be quantitatively compared and selected solely on the basis of the LDEGC. Nevertheless, qualitative considerations, as discussed later in this section, may be sufficient cause to adjust the ranking resulting from the quantitative comparison.

Because of the uncertainty inherent in some of the economic parameters assessed over the entire project time, a sensitivity analysis has to be performed. The expected or probable variation band of these parameters may be estimated. In the sensitivity analysis, the impact of certain parameters on the total plant costs and/or on the LDEGC needs to be assessed. Additionally, a parameter limit needs to be established within which the same decision basis holds. With the results gained from the sensitivity analysis, the LDEGC may be evaluated in a certain band. This evaluation will provide the basis for the economic analysis and the forecast of the total project costs.

For completion of the evaluation, existing risks have to be identified and, as far as possible, converted to cost consequences and included in the economic adjustments. If this is not possible, a qualitative evaluation should be performed with appropriate adjustments being included in the decision making process. The main risks to be considered are connected with:

- Total scope of supply and services;
- Completeness clause for turnkey approach;
- Specified scope in comparison to the offered one (for the multiple package approach);
- Uncertainties in the estimation of the BOP;
- Interface problems for the separate packages of split package and multiple package contracts;
- Delivery schedules;
- Delays in engineering work or hardware supplies;
- Technical guarantees and commercial warranties;
- Licensing procedures and regulatory requirements;
- Financing;
- Escalation, including (real escalation) and interest during construction;
- Exchange rates;
- Fuel and O&M costs.

The details and depth of the evaluation of domestic participation and technology transfer depend strongly on national policy in this matter. Should there be ambitious domestic participation goals and a serious commitment to implement them, then this aspect should become one of the decisive evaluation factors. The assessment of the economic impact of technology transfer is definitely a difficult undertaking because it affects all areas. However, the economic bid evaluation should concentrate on those aspects which affect the nuclear programme.

The computer software package described in Annex II provides a menu driven step by step procedure for obtaining the LDEGC. The financing packages are an integral part of the input to the computer program and the evaluation procedure described.

7.2. ORGANIZATION OF WORK AND USE OF CONSULTANTS AND/OR A/E

A working group(s) should be established by the owner or A/E and the commercial bid packages should be assigned to the different experts within the group to enable them to carry out the economic bid evaluation. The working group(s) should be headed by a project manager who is responsible for co-ordinating the work. It is recommended that bid evaluation procedures and corresponding manuals be prepared, as well as a schedule of activities indicating the principal milestones and dates. The main purpose of the bid evaluation procedure is to ensure consistency and uniformity of the evaluation work to be performed by the various working groups.

The bid evaluation schedule should include all activities, from the receipt and opening of the bids to the submission of the final evaluation report.

The evaluation of the contractual aspects requires the services of a lawyer(s) specializing in international contract negotiations and of specialists with a sound knowledge of industrial, contractual and legal terms and conditions. The owner's evaluation group could be assisted by a competent consultant(s) or A/E(s) as appropriate.

The bid evaluation process may be expected to vary considerably from case to case, but will require a considerable commitment in terms of time and resources. The magnitude of the effort will depend on the number of bids selected for final evaluation, the degree of complexity of the evaluation (e.g. each bid having a different exchange rate as opposed to all bids having the same exchange rate), and the degree of rigour with which the evaluation is carried out. In order to estimate and control the evaluation effort, it is recommended that the bid evaluation schedule include specific evaluation tasks, responsibilities and allocation of resources. Once the schedule is committed, it should be rigorously followed in order to manage the effort within projections. Liberal allowances for effort should be included in the schedule to allow for interaction with the bidders on clarification of bid content, particularly with respect to commercial and financial conditions.

7.3. ECONOMIC EVALUATION PRACTICE

7.3.1. Preparatory steps

The economic evaluation is usually performed by a small team, working closely with the technical and contractual evaluation groups. The team will have computerized tools at its disposal and should have the capacity to modify and adapt them to the specifics of the bids to be evaluated.

The IAEA has updated its comprehensive computer tool for use in evaluating NPP bids. The IAEA computer program for economic bid evaluation (BIDEVAL-3) is based on the updated discussions given in this report and is to be found on the CD-ROM accompanying this report. An illustrative example of an NPP bid evaluation using the BIDEVAL-3 software is presented in Annex II of the CD-ROM.

Among other preparations for the bid invitation, the evaluation group will define the reference currency and cost reference date, and will assess relevant economic parameters (see previous section). Some of these, such as the preferences attributed to local supplies and the discount rate which will be used for bid evaluation, will be included in the BIS. The group will also perform a number of sample calculations and case studies as part of its evaluation, in close co-operation with technical, economic and contractual experts. The management should carefully review these studies.

7.3.2. Information from the bid documents

The evaluation group will take the following and other relevant information from the bid documents:

- Main technical parameters,
- Bid prices,
- Escalation formulas,
- Construction milestones and schedules,
- Payments due at certain construction milestones,
- Amounts covered by financing and loan limits,
- Interest rates,
- Financing fees,
- Grace periods,
- Repayment periods,
- Other financing conditions,
- Contractual terms and conditions.

Some of this information will be entered directly into the input module(s) of the computer tool(s). Other information will have to be evaluated beforehand (e.g. the economic impact of contractual terms).

7.3.3. Information from other bid evaluation areas

Figure 4 is a graphical representation of the interfaces between the economic and technical bid evaluations. The technical bid evaluation provides the basis of cost estimates for deficit or surplus materials, for differences due to different technical designs, for the owner's scope, for fuel and for O&M costs. The latter must include provisions for the costs of future repair or replacement of components, waste management and decommissioning.

Differences in the offered scope of supply and services, as well as the various technical aspects, have to be balanced against the BIS or a chosen reference bid. For the purpose of evaluating economic adjustments in terms of cost, the reference bid should be the most complete bid. With such a reference bid, the evaluator will be able to calculate the required cost differences or to request clarifying cost information from the different suppliers and/or the A/E. The purpose of this step in the evaluation process is to bring the offered bids to a common level, in order to permit a better economic comparison to be made. This process requires a great deal of judgement, knowledge and experience.

Technical and contractual differences in the bids are thus converted, as far as possible, into cost differences or other economic corrections (e.g. longer or shorter construction period, scheduled or unscheduled outages). Qualitative differences remaining have to be clearly identified and assessed in the technical and contractual evaluation reports.

7.3.4. Putting it all together

The economic parameters, data from the bid documents, cost estimates of the owner's scope and economic corrections from the technical and contractual bid evaluation are all entered into an economic evaluation scheme. The economic evaluation methodology is based on the formulas presented in Section 5 and/or the input module(s) of the bid evaluation computer tool(s) (see the example in Annex II of the CD-ROM accompanying this report). Beyond this standard procedure, it is recommended that a number of plausibility checks and sensitivity analyses be performed. Utilities will also use their own evaluation approaches.

A relevant objective of the economic evaluation is to accurately establish payment schedules in all bid currencies. This includes payments:

- By the owner to the supplier(s);
- By the banks and other financing institutions to the suppliers (the latter is the basis by which to calculate interest, fees and loan repayments);
- By the owner to the banks and other financing institutions, both during construction and during the initial years of operation (i.e. until the loans are repaid).

These payment schemes for the capital costs are supplemented by payment schemes for fuel and O&M costs for the economic life of the plant.

7.3.5. Results

When all payments in the required currencies over the economic life of the plant are calculated, they shall be converted to the reference currency in accordance with Section 5.4.6.

The levelized electricity generation costs can then be calculated by dividing the PW of all costs by the PW of the discounted electricity generation during the economic life.

Although the following items are not part of the bid evaluation proper, the available data may also be used to provide other useful information:

- The amount of foreign currency required;
- The cash flow of the project (based on an assumed or postulated electricity price which may vary with time);
- The pay back period for the initial investment;
- The internal rate of return;
- Other economic criteria, e.g. the ratio of gross cash flow to debt service (debt service coverage for the initial operating years).

The results of the economic evaluation lead to an economic ranking of the bids. The results should be summarized in an evaluation report to be presented to management and to the persons involved in decision making.

7.4. TCIC

7.4.1. General

The TCIC of an NPP are the sum of all expenditures incurred in the design, licensing, manufacturing, erection, construction and commissioning of the plant, including financial costs.

As shown in Table II, the TCIC are divided for convenience into base costs, supplementary costs, financial costs and owner's costs. Therefore, the TCIC are the costs incurred in building the NPP and bringing it to commercial operation.

As detailed in Annex II, the import components and the local components of these costs must be entered into the computer program in order to obtain the TCIC. The TCIC also include the import and the local components of the financial costs and the owner's costs. The owner's costs should be included in the economic bid evaluation in order to obtain the costs for the complete plant. Similarly, the costs of options, both those requested in the BIS and those offered by the suppliers, must be entered in the computer program. The usefulness, importance and attributes of these options must be carefully analysed and a decision must be made on whether to add these options or to leave them out.

The local component may be expressed in both the local currency and the currency of the supplier's country. This is done for comparison so that the impact of domestic participation on the cost of certain items can be evaluated and the most economic price of equipment or systems selected.

7.4.2. Assessment of cost consequences of differences in the scope of supply and services and in technical aspects

The cost consequences of differences in the scope of supply and services, as well as in the technical aspects and risks of the offered bids, should be assessed by:

- Identification of differences in the offered scope of supply and services in comparison with the BIS or the selected reference bid,
- Identification of differences in technical design features in the bids relative to the requirements of the BIS or the selected reference bid,
- Identification of all necessary supporting features and information to be provided by the owner or others and as needed by the bidder,
- Assessment of these various differences by means of costs or by a qualitative figure of merit.

The cost estimates for the differences in the scope of supply and services are assessed by taking into account any deficit or surplus materials and/or services with respect to the requirements of the BIS or the selected reference bid. The IAEA system of accounts described in Annex I can be used as a checklist to identify items in the scope of supply for which economic adjustments are required. For certain aspects associated with technical risks, which are not readily quantifiable, a qualitative assessment should be carried out.

For the assessment of the cost consequences of differences in the scope of supply and services, the evaluation procedure includes a comparison for each system, component, structure and service, with respect to the BIS or to a reference bid. If the scope offered corresponds with the BIS no action is taken. If the scope is not well defined, the bidder should be questioned. If there are deviations from the requested scope, the cost consequences of any deficit or surplus materials and/or services should be obtained from the bidders. If this is not possible, cost estimates should be made.

The BIS should specify that the technology offered must be state of the art and be licensable in the country of origin. When there are major technical differences among bids with respect to advanced design features, compliance with the BIS has to be carefully checked. The technical and operational documentation for the advanced features become very important for demonstrating the validity of the design of the offered technology. If the required information is missing from the bid documentation, additional data should be requested from the bidders. The advantages, or even disadvantages, of the various bids should be translated into cost adjustments.

In the evaluation of the cost consequences of various design features, the positive and negative aspects of a design should be quantified. Areas to be considered should include the criteria of reliability, function and performance, safety, O&M and the materials to be used. The anticipated gain or loss of energy, as well as the fuel and O&M costs, should be assessed. Since there are many financial aspects which have great uncertainties, the cost assessment should be limited in practice to areas which can be easily quantified, with all other items being evaluated in a qualitative way.

The following items are taken into consideration in the quantitative or qualitative assessment of the cost consequences of differences in the scope of supply and services and in technical aspects:

- Compliance with the BIS requirements;
- Reactor types;
- Advanced technologies;
- Reliability of components and systems;
- Maintainability of components and systems;
- Materials used in the manufacture of equipment;
- Suitability and ease of in-service inspection to prevent component failure or plant outages;
- Interface requirements;
- Design characteristics and performance of certain components and systems;
- Scope of final documentation for plant licence and operation;
- Guarantees and warranties;
- Availability of spare parts;
- Regulatory climate;
- Safety characteristics of the plant;
- Impact of codes and standards and their ongoing revisions;
- Quality assurance and quality control procedures;
- Operation instructions, including load following capability.

7.5. NUCLEAR FUEL CYCLE COSTS

Nuclear fuel cycle costs include the costs for the front end and back end of the fuel cycle. Front end costs include those for nuclear fuel (uranium supply, conversion and enrichment, if applicable, and fuel assembly fabrication, including transport) and the costs of fuel management activities. Back end costs include those for reprocessing, if applicable, and final storage of high level radioactive waste. If required, the above mentioned costs have to be assessed separately for the first core and for the reload fuel assemblies. The costs of fuel management, fuel management schedules, licensing, preparation or performance of computer training programs, and quality assurance, if offered separately, must be compared for the first core and for the reload fuel. References regarding fuel performance and quality, burnup, long term experience of the supplier and/or warranties should be requirements of the BIS. In addition, revenues achieved through the sale or recycling of spent uranium or through the generation of plutonium or other fissile materials (U and Pu credits), if applicable, have to be established.

The procurement of all the materials and services associated with the nuclear fuel throughout the life of the NPP constitutes a major task for the owner. For the most satisfactory in-core management of the nuclear fuel, the respective fuel management configurations have to be assessed case by case. This work involves not only consideration of technical and economic aspects, but also financing and the dependence of the country on fuel supply.

As mentioned in Section 4.5.2, the BIS requires that each bid include a quotation for the first core and a few reloads. The NSSS manufacturer supplying the first core gives warranties for the equipment and carries out the initial and the final acceptance tests. In addition, a few reloads are offered as an option. The owner should arrange the financing for the first core, as well as for some reloads.

The general procedure for arriving at the different cost components of the nuclear fuel cycle is divided into the following three steps:

- Assessment of costs incurred during the front end activities (mining, conversion, enrichment, fuel assembly fabrication);
- Assessment of costs incurred during the insertion of fuel into the reactor core (fuel management activities), including intermediate storage of spent fuel in the plant;
- Assessment of costs incurred during the back end activities (storage of spent fuel, transport, reprocessing (if applicable), final disposal of high level radioactive waste).

The above procedure must be uniform, so that economic differences connected with the design, material costs, processes and fuel services are accounted for.

The cost consequences of different core configurations, fuel cycle length, burnup, enrichment, use of MOX fuel assemblies, low leakage cores, etc., have to be identified for the different reactor types and bidders.

The first of the above steps consists of preparing a complete breakdown of the front end costs of the fuel cycle, including services. In the second step, a reload plan has to be elaborated for the period up to the equilibrium cycle, considering the offered and guaranteed burnup, and the related cost figures have to be assessed. This procedure is to be repeated for all fuel batches for the reactor operating period. The third step covers all activities and costs for the back end of the fuel cycle. The respective costs have to be assessed.

The assessment of the nuclear fuel cycle costs becomes more complicated when financing considerations have to be included, since many contracts may have to be signed for the different steps. Final, highly active waste disposal is mostly the responsibility of the owner or the country and, therefore, costs related to this item have to be considered separately. Options may be included as appropriate. The cost assessment should be performed with the IAEA computer program described in Annex II.

For comparison purposes, all costs and risks have to be considered in the appropriate currency. In addition, the following risks should be considered:

- Long term supply of fuel,
- Quality of the offered fuel,
- Fuel burnup and performance,
- Licensing,
- Financing.

Special services or service equipment may be specified in the BIS, such as fuel assembly inspection, fuel assembly repair facilities and containers for damaged fuel assemblies. These items should be evaluated separately.

The final evaluation must include a qualitative assessment of those items which can not be assigned as direct costs. The selection process used to identify the best bidder must also consider the long term experience of the supplier, contractual and commercial terms, and development activities for advanced fuel assemblies.

Table VI presents typical reactor and core design parameters for different reactor types. This information may be used for guidance.

7.6. O&M COSTS

The structure of the IAEA account system for O&M costs may be used by the owner as a guide to cost analysis. Reference data for O&M costs may be obtained from experienced utilities, NPP owner groups, the World Association of Nuclear Operators, the IAEA and the 'Nucleonics News'. In the past, the cost consequences of the differences in O&M costs were usually of minor importance in the overall bid evaluation. In recent years, however, differences in O&M costs from design to design and from operator to operator have become more significant, as well as more uncertain. The causes of these include new and different designs, regulatory issues, poor record keeping and retention, changes in design basis and various levels of overcommitment to safety related system/equipment testing. Consequently, it is important that judicious projections of O&M costs be used in the establishment of the total costs for the selected plant.

Power plant O&M costs include all non-fuel operating costs and are generally divided into fixed and variable cost components. These costs are affected by items such as plant staffing and outside support services, consumables, nuclear liability insurance, taxes, interim replacements of energy, inspections, decommissioning, administrative costs and maintenance activities. Plant staffing, however, is the major cost driver, with testing and security staff being significant contributors.

The O&M costs are determined by the size and type of plant and the mode of operation (load following or base load operation) and are largely independent of the energy production. The number of similar units at a particular site has a strong influence on the O&M cost components.

Because of different practices in countries with operating NPPs, the O&M costs should be calculated on a case by case basis, considering the practice and experience in the owner's country.

7.7. POWER OUTPUT AND LOAD FACTOR

7.7.1. Definitions

7.7.1.1. Power output

The minimum/maximum power output required should be clearly defined in the BIS. Examples are as follows:

- For total NPP bid: net electrical output (MW(e)).
- For NI or NSSS bid: steam conditions and flow at steam generator outlet (PWR, PHWR) or at reactor vessel outlet (BWR) (kg/h).
- For turbine generator (TG) bid: gross electrical output (MW(e)) (based on a given steam input).

TABLE VI. ILLUSTRATIVE DATA FOR ENERGY CALCULATION

Items	Reactor types		
	PWR (EPR)	BWR	HWR
Reactor core thermal output (MW(th))	4272	3840	2160
Rated electrical power (gross) (MW(e))	≈1500	1310	≈750
Reactor coolant system:			
Number of loops	4	—	2
Operating pressure (10^5 Pa)	155	70.6	115
RPV inlet/outlet temperatures (°C)	291.3/326.3	215/286	277.9/312.3
Total flow rate (kg/s)	2150	2076	5150
Main steam pressure at full load (10^5 Pa)	72.5	70.6	55.9
Reactor Core			
Number of fuel assemblies	241	784	451
Number of road control cluster assemblies	85	139	18
Fuel assembly array	17 × 17–25	8 × 8 (9 × 9)	37
Active height (cm)	420	371	530
Average linear heat rate (W/cm)	155	204.4	232
Maximum enrichment (wt%)	≤ 4.9	2.75 (mean)	0.711
Total inventory of fuel (Mg)	141	≈139	85.1
Batch weight reload (Mg)	47	35	Continuous
Batch discharge burnup (MW·d/kg)	≤ 60	37	7.5
Status	(1997)	(1984)	(1997)

The gross power output (MW(e)) measured at the output terminals of all generator sets in the station includes the auxiliary power taken by the station and losses in transformers that are considered integral parts of the station.

The net power output (MW(e)), which is the maximum power that can be supplied, is measured at the station outlet terminals, after deducting the power taken by the station auxiliaries and losses in the transformers that are considered integral parts of the station.

The steam flow (kg/h) and conditions at the steam generator outlet or vessel outlet are measured using an officially authorized method established in the respective technical code.

One of these physical parameters is subject to warranties and is part of the contract. The required values are established in the BIS. Furthermore, the tolerances have to be specified and agreed upon (±X% of the specified values) by considering the grid characteristics at the time of initial commercial operation of the plant. In the case of the NSSS, the steam rates and conditions as well as tolerances must be specified and agreed upon. In the case of the TG package, input steam flow rates and conditions (including tolerances) as well as output power (including tolerances) must be specified and agreed upon.

7.7.1.2. Load factor

The load factor, LF(%), of a plant for a reference period (a) is defined by:

$$\mathrm{LF}(\%) = \frac{E}{E_m} \times 100 \tag{19}$$

where LF is the load factor (%), E is the net electrical energy (MW(e)·h) produced during the reference period under consideration and E_m is the net electrical energy (MW(e)·h) which would have been produced at maximum net capacity (MW(e)), under continuous operation during the entire reference period (definition in accordance with the IAEA's power reactor information system).

As expressed by the formula, the load factor for a unit or station for a given period is the ratio of the energy that is produced during the reference period to the maximum energy that could have been produced under continuous operation over the reference period.

Care must be exercised in specifying a load factor in the BIS. Attainment of a high load factor requires superior, or at least above average, plant performance in the following areas: system/component reliability, maintenance and mode of operation. This infers the need for quality technical design, qualified O&M staff and preventive maintenance. Of additional importance, however, is the economic dispatch of the plant's electricity. If the electricity unit cost is low and the system demand is high, then the plant's generation will be mostly or fully dispatched. Since the electricity demand is beyond the control of the contractors, as well as the owner, the specification of a load factor for any purpose would necessitate specifying the operating conditions for which the load factor is required. It is not likely that these plant performance elements will be within the complete, comprehensive and continuous control of the contractor for any of the first three types of contract discussed in Section 3. Nevertheless, a load factor under certain operating conditions may be specified in the BIS so as to act as a reference point in the evaluation process.

7.7.2. Assessment of power output and load factor

A choice of unit size must be made during the feasibility study that leads to a decision regarding the issuance of the BIS. The unit sizes actually available from suppliers at that time should be taken into account since the choice of certain sizes may limit the number of bidders by excluding some. By issuing a prequalification bid request, it can be established which suppliers are interested in bidding and also which sizes will be offered. This can assist the final BIS preparation and ensures that desirable bidders are not excluded.

With respect to the power output of the NPP, several solutions are feasible. Power output should be specified in the BIS, with due consideration given to the future plans of the owner's country regarding electric grid expansion. The most common solutions are:

(a) Single unit, with specified net power output and an allowable tolerance, e.g. 300 MW(e) ±5%, 650 MW(e) ±5%, 1000 MW(e) ±5%, 1300 MW(e) ±5%, 1500 MW(e) ±5%.
(b) Double unit, with specified net power output and an allowable tolerance, e.g. 2 × 650 MW(e) ±5%, 2 × 1000 MW(e) ±5%, 2 × 1300 MW(e) ±5%.
(c) One site or several sites, with specified net power output, leaving open the number of units to be offered, e.g. 2000 MW(e) ±10%, made up as 2 × 1100 MW(e) or 2 × 900 MW(e) or 3 × 650 MW(e).
(d) One site or several sites, with specified net power output and specified number of units, e.g. 2 × 2 × 1000 MW(e): 2 × 1000 MW(e) ±5% for site A, 2 × 1000 MW(e) ±5% for site B.

If the offered power output corresponds with the power output stated in the BIS as being within the allowable range, then the bid should be evaluated on the basis of the power output offered. If the offered power output is outside the allowable range, it is up to the owner to decide how to consider the particular bid in the economic evaluation process. If the offered power output is above the specified value, it has to be decided how much of the extra capacity can be absorbed by the grid, taking into account the grid expansion requirements. There may be additional costs from the required grid expansion and the maintenance of a reserve margin. The reserve margin requirements increase with increasing unit size.

The bids have to be assessed by considering the load factor together with the type of power plant as specified in the BIS. If the offered load factor is lower than that required in the BIS, the bid should be penalized because of reduced annual power output. In some cases, the offered load factor may be higher than that required in the BIS but is subject to warranties and is supported by experience from a similar plant running under comparable conditions. Such an offering should be considered as an advantage and this advantage should be quantitatively evaluated by the owner.

The offered plant load factor and power output should be combined and the bid which promises the highest amount of energy during the reference period may be favoured with respect to the other bids. This is accounted for automatically in the proposed evaluation method which is based on the LDEGC.

Figure 14 is based on the assumption of a plant lifetime of 30 years and illustrates the influence of different mean load factors on the energy generation over that period. The differences in energy generation of the common plant sizes demonstrate the significance of the load factors. For instance, for a plant with 900 MW(e) output, the energy generation increases by 33% when the load factor is increased from 60% to 80%. Operation of a plant on the highest load factor point results in greater economic benefits. If the differences are capitalized, several billions of US dollars can easily be accumulated. In the case of an NPP with a lower than average load factor, there will be considerable incentive to target that plant for improvements.

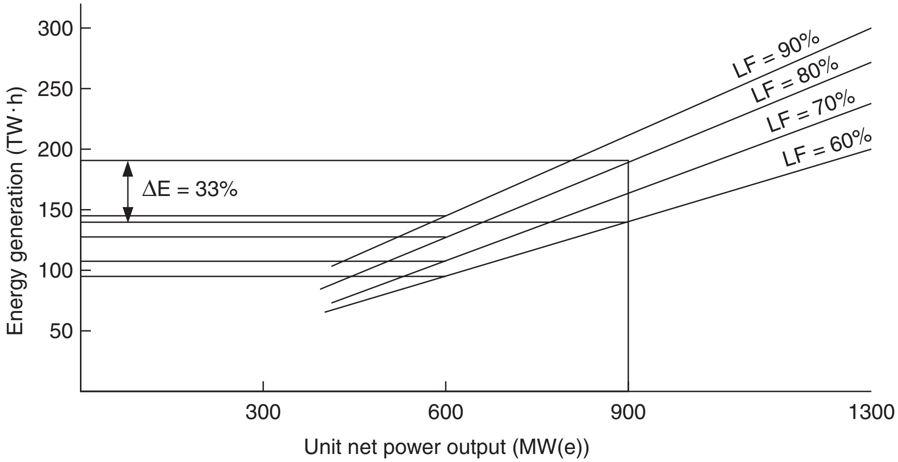


FIG. 14. Influence of plant load factors (LF) on energy generated over 30 year period (mean values over plant lifetime).

7.8. COST ASSESSMENT OF ECONOMIC PARAMETERS

The economic parameters described in Section 5.4, namely project time and project schedule, escalation, economic life, discount rate, IDC and currency exchange rate, have to be analysed with respect to their impacts on the total plant costs. The necessary information must be extracted from the various bids and other sources (e.g. discount rate from the government or national banks) and compared with the parameters for the reference bid. Noteworthy differences have to be converted into cost figures and added to the TCIC. They must also be considered in the financing programme.

7.9. ASSESSMENT OF COMMERCIAL AND CONTRACTUAL CONDITIONS

The detailed assessment of the commercial and contractual conditions (refer to Section 3.3) for some items is discussed in the following paragraphs. The scope of the assessment depends on the scope of supply and services requested in the BIS. This may be expanded or restricted as desired.

7.9.1. Licensability, rules and regulations

The draft contract must contain an agreement on a reference date of validity for national and/or international codes, regulations and requirements, and the scope of documentation for licence application.

In the BIS, the owner should give a detailed description of the licensing procedure to be followed. The plant should be licensable in the country of origin and designed in accordance with that country's prevailing codes, standards and regulations.

The risks associated with changes in the licensing requirements can not be accurately assessed at the time of bid evaluation. However, these risks should be estimated and evaluated for the different suppliers in terms of changes in the scope of supply and services and/or schedule delays. It is advisable to set up a contingency allowance for unforeseeable events resulting from changes in the licensing requirements in the supplier's country. The purpose of the contingency is to offset related increases in cost above the amount agreed to in the contract. Additional requirements issued in the owner's country normally have to be borne by the owner.

7.9.2. Alternatives and options

In the assessment of the different bids, any options offered and accepted for the O&M of the plant could be assumed to be in compliance with the BIS. Conversely, these options may be considered as an alternative to the base technology offered or recommended by the bidder. The selection of the required alternatives and/or options should have been made in the technical bid evaluation. Options offered in the bid that are desirable, but not an absolute necessity for plant O&M, may also be selected in the technical bid evaluation. If these options are not offered by every bidder, the bidders not offering the option should be given the opportunity to do so. If this is not done, unnecessary options arbitrarily included in the evaluations could adversely displace the bid order in the final evaluation ranking, thereby raising litigious issues regarding fairness. In any event, all of the alternatives and options selected in the technical bid evaluation should be included in the entire assessment process.

The costs of any selected alternatives and/or options have to be added to the TCIC and assessed as previously described. If the decision on whether an offered option should be accepted or rejected is postponed until the construction period, additional investment may be expected and has to be taken into account.

7.9.3. Spare parts

In most cases, a scope of spare parts (including wear parts) for a specified operation period is required in the BIS. However, a definite scope of spare and wear parts can not be given in the BIS since the operability and maintainability features of the different reactor plant designs vary to a great extent. Furthermore, the scope of spare and wear parts depends on the contract model envisaged. Nevertheless, the different packages offered have to be compared in the assessment procedure, in order to identify the most important and costliest components. These may have to be evaluated on a case by case basis. The majority of the smaller parts can only be compared on a package price basis. In order to provide guidance for the owner, a requirement should be placed in the BIS whereby bidders include a list of recommended spare and wear parts and their prices in their bids. The list should be consistent with the bidders' warranties and recommendations for O&M. For comparison purposes, the additional costs for spare and wear parts have to be added to the TCIC.

For long term planning, the owner should not only specify the desired spare parts during the first five operating years, but should also investigate the availability of spare and wear parts over the entire lifetime of the plant.

7.9.4. Changes in the scope of supply and services

During plant construction, changes in the scope of supply and services may arise. Changes in licensing requirements that are initiated by the authorities can not be foreseen. In most cases, it is required in the BIS that the most modern technology available in the supplier's country be applied. Additionally, it is required that the offered components or services be licensable in the supplier's country at the bid presentation date. Changes and/or modifications initiated by the owner should be kept to a minimum as they lead to change orders, resulting in increased costs. Consequently, careful and thorough generation expansion planning and decision making prior to preparation of the BIS is essential in ensuring a cost effective plant purchase. Nevertheless, from experience gained in previous projects, it is known that a certain percentage of investment in additional equipment and software has to be assumed. These contingency costs have to be added to the base costs in monetary cost terms or as a percentage and have to be assessed in the economic bid evaluation process. If the change order work has an impact on the 'critical path', a time extension in the project schedule may be necessary. This extension will increase time related construction costs and may incur a penalty in the form of replacement power costs when the additional power is not available as planned. Such time extensions must be negotiated and included in a contract change order. These changes may vary and should be mutually agreed upon by the parties. Any equipment and changes required during construction by the supplier's nuclear regulatory commission should be included in the bid to a certain extent.

For scope changes, the type of contract plays an important role and the consequences of the possible changes in the specified scopes must be evaluated. The impact of the expected scope changes is difficult to estimate in the case of interfaces or the BOP. The additional uncertainties have to be considered in the risk analysis. Some aspects that have to be considered in the scope change assessment process are discussed below for the different contract types.

7.9.4.1. Turnkey contract

Normally with a turnkey contract, the lowest risk of change in the scope of supply and services can be expected. However, it is recommended that extra money be allocated as a contingency measure to cope with unforeseeable costs (e.g. costs arising from changes in licensing requirements).

7.9.4.2. Split package contract

If a split package contract is selected for the project, it is necessary to describe all boundaries in the scope of supply and services and to specify all interfaces as precisely as possible. However, the risk of changes and/or modifications in the hardware scope and of additional services for balancing the different packages is very high and remains with the owner. In the assessment of the different bids, it is recommended that the scope of supply and services offered be analysed and compared with a turnkey project. This makes it easier to estimate the additional cost of changes. A contingency allowance is required to cover the extra unforeseeable costs and should be added to the total capital investment requirements.

7.9.4.3. Multiple package contract

In the case of a multiple package contract, there may be more reasons for additional scope and consequently the level of uncertainty is much higher than in the other types of contract. When the technical evaluation process has finished, the costs to be expected must be calculated and included in the evaluation process as an integral part of the total plant investment costs. A contingency allowance is required.

7.9.4.4. BOO and BOOT contract

Refer to the discussions on BOO/BOOT in Section 3.

7.9.5. Taxes, duties and fees

Taxes, duties and fees which have to be considered for the import part and the domestic part of the work have to be assessed on a case by case basis. Export taxes charged by the supplier's country must be included in the offered bid prices and are part of the TCIC. Special fees, which are included in the financing proposals or in the fuel handling costs, should also be added to the TCIC. Special duty or import taxes which have to be paid in the owner's country may be accounted for as owner's costs.

7.9.6. Government authorization

Certain countries have signed the Treaty on the Non-Proliferation of Nuclear Weapons (NPT) and/or have agreed to comply with the undertakings of the NSG, as detailed in two IAEA information circulars.[2] These treaties and agreements require

[2] INTERNATIONAL ATOMIC ENERGY AGENCY, Communications Received from embers Regarding the Export of Nuclear Material and of Certain Categories of Equipment and Other Material, Information Circular No. 209 (Rev. 1, Add. 3), IAEA, Vienna (1994).

INTERNATIONAL ATOMIC ENERGY AGENCY, Communication Received from Certain Member States Regarding Guidelines for the Export of Nuclear Material, Equipment and Technology, Information Circular No. 254 (Rev. 3, Part 2), IAEA, Vienna (1998).

that nuclear materials and equipment be exported in accordance with the condition that their use will be subject to safeguards under an agreement with the IAEA. Information Circular No. 209 identifies specific equipment and non-nuclear material whose export triggers IAEA safeguards and is known as the ‘trigger list’. In addition to parties and prospective parties to the NPT, members of the OECD and participants in such agreements as the Treaty of Tlatelolco may already have such agreements with the IAEA or have procedures that meet or exceed IAEA safeguards. The purpose of the safeguards is to ensure that exported nuclear material and equipment will only be used in civilian nuclear power programmes. If the owner’s country is not a party to any of these agreements, other arrangements will need to be made (e.g. the Quatropartite agreement between Argentina, Brazil, the IAEA and the Brazilian–Argentine Agency for Accounting and Control of Nuclear Materials.

In any event, discussions among the owner, the supplier and the export licensing authorities should be arranged at a very early stage of project planning. The purpose of these discussions should be to identify what needs to be done by each party to gain compliance with government requirements for the export of nuclear materials and equipment. Additionally, the discussions should identify the participants’ responsibilities and provide an estimated timetable that will lead to the granting of an export licence. This has to be certified by intergovernmental notes. To ensure that these negotiations will be initiated, the owner should include in the BIS a requirement that an official export licence be issued by the government of the supplier’s country. In addition, arrangements should be made by the owner for the issue of an import licence that is based on the dates for receipt of the exports, according to the proposed project schedule. Any other official government authorization that may be required for an NPP project should also have been requested in the BIS.

Generally, the effort required to obtain these kinds of government authorization does not have a significant cost impact. It does, however, increase the risk of causing an extension in the project duration, if the required licence can not be obtained in time. The increase in project duration could cause significant increases in project cost and financing. To protect the owner against these events a contingency may need to be applied.

7.9.7. Insurance

The owner’s and the supplier’s insurance for the period of project implementation should be analysed as regards the extent of coverage and costs. The applicable insurances are:

- Nuclear liability insurance;
- Workers compensation insurance;

- Comprehensive insurance (i.e. fire, water, theft);
- Automobile insurance;
- Transportation insurance;
- Storage insurance;
- Builder's risk insurance;
- Erection insurance;
- Third party liability insurance;
- Health insurance.

An alternative approach would be a project insurance taken out in the name of the owner and which covers all project risks.

The insurance premiums have to be assessed and compared in the bid evaluation process, especially for package contracts. In addition, a comparison of the insurance limitations and responsibilities has to be made. A qualitative assessment of the cost consequences may be necessary.

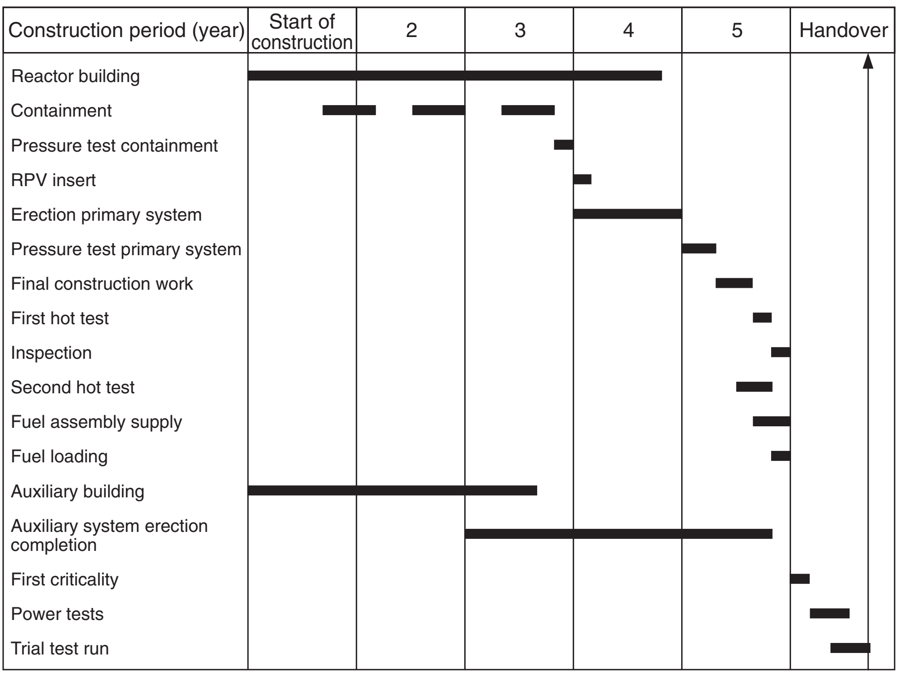


FIG. 15. Construction schedule for a 1300 MW(e) NPP.

7.9.8. Training of O&M personnel

The assessment of the training needs of O&M personnel depends on the type of contract and the scope of services required in the BIS. The programmes offered vary regarding the number of people to be trained, their professional background and their experience. Other aspects to be considered are the training location and language courses taken abroad. Usually, many alternatives are offered in the bids and it is not easy to compare the different proposals. It is recommended that an assessment be made of the number of people to be trained for the different qualification levels as well as the number of person-months. These figures can be converted to costs and added to the TCIC. Furthermore, details concerning simulator training and/or on the job training should be assessed and accounted for in the cost figures.

7.9.9. Schedule of deliveries

The presentation of delivery schedules and the corresponding project schedule is required in the BIS. An example of a construction schedule is shown in Fig. 15. The details of delivery schedules depend on the type of contract envisaged. The assessment of the payment plan, which is linked with clearly defined events or milestones in the delivery schedules, has to be analysed for completeness and for subsequent evaluation. An example of a payment plan is shown in Table VII. As

TABLE VII. PAYMENT PLAN FOR AN NPP (EXAMPLE)

Installment number	Percentage of price	Months after contract effective date	
0	5.0	0	Contract effective date
1	2.5	6	Start of construction
2	10.0	12	Containment construction
3	12.5	18	Auxiliary building
4	15.0	24	Manufacture of heavy components
5	10.0	30	Assembly of auxiliary systems
6	5.0	36	Containment pressure test
7	10.0	42	Primary system pressure test
8	10.0	48	Commissioning
9	5.0	54	Fuel assembly delivery
10	7.0	60	First criticality
11	3.0	66	End of trial test run
12	5.0	72	Hand over

outlined in this example, the instalments for the components and systems correspond with the number of months from the reference date. To tie the schedule and the cost evaluation together, the line items in the payment plan should also be identified with their corresponding IAEA account number. These dates constitute the basis for the calculation of the escalation and the IDC, as well as providing the basis for the financing arrangement. A risk assessment for the different delivery schedules should be made, taking into consideration reference projects constructed under conditions similar to those of the project under assessment. In particular, the influence of domestic supplies and services on plant erection and construction has to be evaluated with regard to possible delays and their cost consequences. For the domestic supplies and services, there may be different degrees of supplier responsibility, even in a turnkey project.

7.9.10. Penalties and bonuses

Penalties are provided in the contracts for technical and commercial reasons, and to give the owner some leverage in order to ensure reliable performance by the supplier(s) regarding the offered products. Penalties are requested in the BIS for different purposes and the bids have to be compared with regard to their range of penalties. Mostly, penalties are requested for:

- Delays in delivery of complete plants, or parts of the plant, or components;
- Unsatisfactory technical performance of complete plants, or parts of the plant, or components;
- Late delivery of software;
- Problems arising from domestic participation.

Detailed analysis of each penalty, comparison of all penalties and assessment of the total limiting value should indicate the reliability of the offered scope of supply and services with respect to data, schedules and procedures.

Alternatively, the BIS may offer bonuses as well as penalties in the same areas as those outlined above as a more positive means of providing incentive for reliable and timely performance. In this case, the magnitude of the bonuses and penalties would need to be stipulated in the BIS, as well as the conditions under which bonuses would be awarded and penalties imposed.

7.9.11. Guarantees and warranties

The guarantees and warranties desired by the owner should be specified in the BIS and should be assessed in the bid evaluation process, taking into account the following points:

- Date of project completion;
- Date of delivery (NSSS, TG, major components), including delivery times for software and hardware;
- Heat rate (at steam generator outlet or pressure vessel outlet);
- Load or availability factor (see Section 7.7.1);
- Net electrical power output (turnkey) or gross electrical power output capacity (TG), and steam output and conditions (NI or NSSS);
- Fuel performance, including fuel integrity and burnup;
- Economic responsibility for the replacement or repair of equipment, including transport costs;
- Quality of materials, equipment and workmanship (for a limited period of time);
- Compatibility of refuelling batches with in-core fuel (physical data, mechanical data and fuel management history);
- Extended warranties for special components and/or equipment;
- Load following capability;
- Heavy water losses (for a limited period of time).

In the case of deviations from the requirements outlined in the BIS, penalties and bonuses may be assessed.

7.9.12. Delays

In most cases, the suppliers include in their proposals a list of causes of excusable delays, such as the following:

- Delays caused by problems with labour, equipment, materials, services, authorizations, etc. (causes not attributable to the supplier);
- Delays or deficiencies in transport;
- Force majeure.

Labour unrest, an unstable social climate, and deficiencies in the transportation system and other necessary infrastructures will increase the probability of delays. These causes, which involve additional risks, should be assessed with equal weight for all bidders according to international law and practice. Only large deviations from the schedules and delay related exceptions (some bidders may include more excusable delays than others) should be considered on a case by case basis. Force majeure delays are events that can not be reasonably foreseen, or if they can be foreseen they can not be avoided. Incidents that are considered under force majeure are earthquakes, floods, fire, war, nuclear incidents, sabotage, epidemics and strikes.

Non-excusable delays on the part of the supplier(s) for the scope of supply and services can only be evaluated by considering the experience gained from similar projects and from experience of the same subcontractors employed in the manufacture and assembly of components, systems and software. Such delays result in an extension of the project time and in additional costs to the owner. These costs may be estimated by considering the impact of the delays on the project schedule, as well as other related factors (replacement of machinery and/or additional services). Although a general rule on how to estimate the costs of probable delays can not be given, the owner should be prepared to allocate extra funds to cover these risks and their associated costs.

The cost consequences of delays are taken into account in the assessment of cost increases, including escalation and higher IDC. Furthermore, costs must be estimated on a case by case and best effort basis.

7.9.13. Payment schedule

The assessment of variations in the payment schedules has to be made on the basis of the payment plans offered. The differences and/or variations have to be calculated on a case by case basis. The cost consequences have to be calculated and additions to or subtractions from the TCIC have to be made. The consequences of variations in the payment schedules are taken into consideration partly by the assessment of escalation and IDC. Table VII shows, as an example, a payment plan for a turnkey plant having a construction time of 66 months.

7.9.14. Termination and suspension of contract

The termination and suspension of a contract initiated by the owner or supplier can not be foreseen at the time of bid evaluation. However, the probable cost consequences may be considered as a risk. The risk can be limited to a certain extent by careful selection and qualification of the supplier and by checking its reputation and reliability in the international market.

If the suspension and/or termination of the contract rests with the owner, the supplier must be indemnified up to the date of suspension and/or termination.

After termination or suspension of a contract, very difficult and protracted negotiations may follow. In most cases, a final decision is only reached by arbitration. Because of the very low probability of this event, termination and suspension of a contract should not be a subject of the economic bid evaluation.

7.10. TOTAL PLANT COSTS

7.10.1. TCIC

The TCIC are those needed for building the NPP and bringing it to commercial operation. As already explained in Section 4, the TCIC incorporate the base costs of the systems, components and various kinds of engineering cost, the supplementary costs, the financing costs and the owner's costs. The base costs and some of the supplementary costs can be obtained from the bids together with the financing costs. The owner's costs are accounted for separately. The various cost components have to be assessed very carefully, as described in the previous sections, because differences among the various bids will strongly affect the overall result of the economic bid evaluation. The TCIC are very important for ranking the bids and selecting the best bidder.

7.10.2. Nuclear fuel cycle costs

The nuclear fuel offered in the bids may include the first core and some reloads. The costs for the front end as well as the back end of the fuel cycle must be assessed, including the option of using MOX fuel. The fuel cycle strategy (burnup cycle length) should be offered with the bids and should be carefully assessed in the bid evaluation process. Furthermore, the financial costs associated with the first core and those reloads that are offered must be included in the evaluation. For LWRs, the cycle time should be agreed upon with the bidders, because this will be the basis for ordering the reload fuel after the offered reloads are consumed. Continuous refuelling during power operation, as in the case of the HWR, requires the availability of sufficient reload fuel. Summarizing the above facts, the TCIC of the fuel cycle should be well established in the economic bid evaluation process.

7.10.3. O&M costs

The O&M costs should be classified according to the O&M account system and be estimated by the owner (see also Section 7.6).

7.11. CONTINGENCY AND RANGE ESTIMATION

The impact of risks identified in this section may be accounted for in the bid evaluation by developing cost contingencies to be applied in the LDEGC calculation. As previously discussed, the number of risks considered can be greatly reduced through the use of sensitivity analysis, so that contingencies need be developed only for risks having significant cost consequences. Software for cost/risk analysis, schedule/risk analysis and range estimation is commercially available.

Generally, risk analysis software requires the user to select an appropriate probability distribution function in a Monte Carlo type approach in order to develop a contingency amount for a specific purpose. The input to this process is a methodical series of expert estimates of the likely magnitude and probability distribution of cost variations in each risk area of interest. Range estimation software, on the other hand, provides a simplified approach to cost/risk analysis, requiring only simplified inputs of ranges and probability factors, rather than probability distribution functions and their parameters. Range estimation software also provides a means of assessing the amount that should be added to an estimate in order to reduce the risk of cost overrun in the estimate to a selected level.

Application of a contingency to an NPP cost estimate, or to the various parts of the estimate, is an effective means of reducing potential monetary loss from inherent economic risks. Contingencies are those monetary allowances applied to construction cost estimates to account for uncertainties that are associated with the technical, cost and construction data on which the cost estimate is based. Using range estimation techniques, a range of contingencies and associated confidence factors may be provided at the IAEA account system three digit level of detail (as a minimum). These would establish the per cent confidence of no cost overrun for the addition of a contingency amount to the estimated cost. Commercial personal computer based programs for range estimation are available to develop these contingencies and confidence factors.

Generally, a range estimation program for each defined cost category requires:

- An estimate of its target value,
- A projected possible high and low value for the target value,
- An estimate of the probability that the actual value of the target will fall within the range of the estimated high and low values.

A range estimation approach for calculating contingencies and associated confidence factors for an NPP overall cost estimate may be implemented in accordance with the following steps:

Step 1. Select a minimum of 30 major cost categories (15 equipment/material costs and 15 associated installation labour (including supervision) costs) from the cost estimate, which reflect both the major cost drivers in the estimate and the total estimate.

Step 2. Using the 30 cost category values selected in Step 1 as 'target costs', develop the following elements, as applicable, with the assistance of experts having relevant and extensive experience:

- Four (4) components of high and low cost uncertainty estimates (CUE) in per cent for each of the target cost amounts:
  — QCUE: Accuracy of estimated construction **Q**uantities
  — CQUE: Allowance for delays in the **C**onstruction process
  — UQUE: Ability to construct/operate **U**nproved systems
  — LCUE: Potential to complete the **L**icensing process.
- A probability factor in per cent for each of the target costs.

Step 3. Using the CUE component input data from Step 2, calculate the composite high and composite low CUE amounts for the 30 cost categories.

Step 4. Enter the target costs and the probability factors from Step 2, together with the composite high and low CUE amounts from Step 3, into a range estimation program to calculate the associated range of plant contingency amounts and their confidence factors:

Suggested range estimation cost categories for an NPP on a 15 category basis are:

Reactor building	Reactor equipment	Condensing systems
Major auxiliary buildings	Safeguards system	Remaining turbine equipment
Control room	Reactor I&C	Electric plant equipment
Remaining structures	Remaining reactor equipment	Main heat rejection system
NSSS	TG unit	Remaining plant equipment

The quality of the information generated by this method depends on the reliability of the available input data. High contingencies recommended in certain areas as additional investment costs may penalize the results of the economic bid evaluation and lead to further discussions and evaluations. Contingencies that are estimated at too low a level may not cover cost overruns, which may lead to financing problems during the construction period. To evaluate the results in the most appropriate manner requires a great deal of experience in this field. Consequently, the addition of risk evalua-tion experts to the assessment team is an absolute necessity. The method described is one solution for solving risk problems. However, others may also be applied.

TABLE VIII. COST ITEMS FOR EXPORTS AND TYPES OF SUPPLIER SALE PRICES, DEPENDING ON CONTRACT CONDITIONS, IN ACCORDANCE WITH DEFINITIONS IN THE ICC INCOTERMS[a]

Cost buildup	Sale price per INCOTERMS definition	
Supplier net sale price (at the factory)[b]		
+		
Packing	EXW	Ex-works
+		
Insurance and transport costs up to the export harbour	FAS	Free alongside ship
+		
Export licence and its cost, and duties and taxes for the exports	FOB	Free on board
+		
Insurance and freight costs up to the import harbour	CIF	Cost, insurance and freight
+		
Import licence and its costs, taxes and custom duties at the port of delivery	DEQ	Delivery, ex-quay, duty paid
+		
Insurance and inland transport costs to the site	DDP	Delivery, duty paid

[a] ICC INCOTERMS, published by the International Chamber of Commerce, are used worldwide to specify the obligations for delivering goods in international contracts. The terms shown in the example are typical, but do not represent all possibilities. For details of all terms, refer to the INCOTERMS 1990 issue.
[b] For export outside the EU, the exporter may be reimbursed for the VAT paid by the main supplier to the subsupplier of the goods in the country of origin.

7.12. COST BUILDUP FOR IMPORTED EQUIPMENT

To assist the owner in making cost buildup calculations, the various cost components that have to be considered are given in Table VIII. The cost components mentioned are of specific interest for package contracts or for single component orders. These cost components have to be added in order to obtain the total cost of the considered imported equipment.

8. TECHNOLOGY TRANSFER

8.1. INTRODUCTION

The introduction of nuclear power and nuclear technology in a country gives rise to singular problems and considerations for industrial and other infrastructures. There will be new requirements for the industry and it will be necessary for governments to undertake additional commitments on a long term basis. Only a long term nuclear power programme, incorporating a series of NPP projects, can justify the sizeable effort needed. What must be accomplished is the planning and implementation of the national infrastructure development and the supporting organizational structures and activities. Such a programme would need to incorporate a series of NPP projects.

Although electricity generation will generally be the primary objective of a nuclear power programme, other benefits may be derived from it. The implementation of an NPP may include technology transfer, in addition to domestic participation. Many essential activities for domestic participation should be considered and the technology 'spin-off' effects that benefit national industrial development should be carefully analysed. In the long run, a country in which an NPP is established may become independent to a certain extent in some areas, e.g. mechanical and electrical industries. Also, technology transfer may have an impact on other important industries, such as the chemical and petrochemical industries and shipyards.

With regard to technology transfer for the first NPP, careful studies have to be performed to analyse the local capabilities in detail. All information needed has to be collected by the bidders on a case by case basis, so that they can make a detailed proposal for a technology transfer programme in their bids.

The analysis should identify the already existing capabilities in all areas connected with a nuclear power programme. Furthermore, a plan for the future development of the local industry and infrastructures should be elaborated, including budget planning. The results of such a study should be the basis of contract proposals for the first NPP project (turnkey, split package or multiple package as described in Section 3). The possibilities for the expected technology transfer programme should be explained in the BIS.

In evaluation terms, the technology transfer package should be clearly stated as forming a sizeable portion of the total bid package.

Actual evaluation and comparison of competing bidder's technology transfer packages will find many differences and will generally result in a subjective qualitative assessment being made. However, if the owner has assembled experts to provide assessment and advice, a well founded and informative report on the technology transfer package and domestic participation could result and weigh heavily in the overall bid evaluation process.

8.2. GENERAL CONSIDERATIONS

A technology transfer programme, established mainly between the supplier's country and the buyer's country, comprises several steps. Technology transfer may be agreed among:

- Governments, and regulatory and licensing authorities;
- Technical expert organizations;
- Research institutes (scientific co-operation in energy sectors);
- Industries and utilities (NPP design and construction, component manufacture, maintenance, operation);
- A/E firms.

If the above mentioned entities decide on a technology transfer programme, the agreement between the various organizations or entities should be mutual and made far in advance of the NPP project. The resources of personnel, infrastructure, industry, research institutes, technical high schools and universities, as well as the licensing authorities, have to be qualified sufficiently early in time, especially in the buyer's country. The preconditions for co-operation in the implementation phase of a nuclear power programme depend on a common understanding of the steps needed. Normally, the governments initiate the scientific programme and mutually agree that it is not directly linked to the NPP. The degree of experience and the level of education of the staff available dictate the technology transfer programme. The owner has to decide on many subjects as early as the pre-project phase, i.e. site selection and site qualification, infrastructure, railways, trucks, harbours, cranes, preparation of the BIS and preliminary safety analysis report, financing reviews and planning, recruitment of project management staff, and engineers for safety and operational systems. These activities can be performed within:

- A commercial contract;
- A technology transfer agreement, whereby the owner's staff are incorporated in a consulting company;
- A technology transfer agreement with an NPP supplier, which may become the contractor at a later date;
- A technology transfer programme between utilities, co-operating under the umbrella of a separate technology transfer agreement.

The qualification programme for the various industries in the owner's country has to be undertaken by the prospective supplier(s), together with the manufacturers from both countries. An important result revealed by this industry survey analysis is the budget necessary for new workshops. Another important result concerns the organization of the qualification of personnel for engineering, manufacturing and quality assurance. Deficiencies in qualifications can be compensated for by arranging a training and qualification programme, and job sharing among manufacturers.

In the economic bid evaluation, it must be recognized that the technology transfer has short term and long term implications. Among the short term benefits, the transfer of the technology for design and construction of the NPP is of paramount importance. Also, since technology transfer is a long term venture, the backup area (research and development) is important. Research and development activities can help in the process of adapting the existing technology to the requirements of the specific technology for a nuclear programme. The technical and economic evaluation teams should perform quantitative and qualitative analyses, with the two groups working closely together.

A few principles to be followed in the transfer of technology are suggested:

- The technology to be provided should be appropriate to the conditions in the owner's country.
- The supplier should be capable of providing the requisite training of key personnel in the owner's country, and should be under obligation to provide such training. Some of this training may be given at the headquarters of the supplier, where trainees can better appreciate the scope of what is involved.
- The licensed technology should utilize, as much as possible, local resources, including raw materials, labour skills and supervisory personnel.
- The activity should benefit the economy of a country more than import substitution would achieve alone.
- The import of licensed technology should have a positive spin-off, such as encouraging the growth of certain local support and supply industries.

Licence agreements with organizations and enterprises in the owner's country should contain provisions by which technology transfer can be accomplished efficiently without creating areas of uncertainty which might lead to future disagreements. Even if the recipient entity is a joint venture, partially owned by the supplier or industries in the supplier's country or multinational entities, it is wise to clearly define the conditions of the technology transfer in a formal agreement.

8.3. DOMESTIC PARTICIPATION

The scope and level of domestic participation will vary according to the specific conditions prevailing within each country and will depend on national policies and infrastructures. It will also depend on the influence of various limiting factors, such as the cost of local products, financing investment capability, adequate market size (local and abroad), qualified personnel, industrial capability and quality standards, technology and know-how, and nuclear safety and non-proliferation aspects.

Domestic participation has advantageous and disadvantageous aspects, which must be taken into consideration when starting an NPP. Some of the expected advantages and disadvantages for a developing country could be the following:

Advantages

- Reduced imports,
- Foreign currency savings,
- Job creation,
- Development and improvement of the domestic industry,
- Improvement in the quality of industrial products,
- Development of highly qualified personnel,
- Cost savings,
- Development of self-reliance for nuclear power projects.

Disadvantages

- Higher price of domestic products,
- Inexperience in project management activities,
- Reduced quality control,
- Increased burden on the financial resources of the buyer's country,
- Delays in delivery.

In general, the benefits derived from domestic participation in a nuclear power programme are not limited to this programme. The potential impact of these benefits on the technological development of the entire country can be very large.

It is highly recommended that a minimum domestic participation programme be requested in the call for bids. The necessary precautions and activities should be developed with great care. Some examples of these and the subjects covered are outlined below:

- Active involvement of owner's staff in project management and O&M.
- Implementation of quality assurance procedures.

- Nuclear regulations and licensing issues.
- Radiological protection and environmental surveillance.
- Waste management of low, medium and high level waste.
- Public information and public acceptance.
- Safeguards and physical protection.
- Involvement in design reviews (split or multiple package contracts).
- Site preparation, including interfaces between the various site installations, site village, traffic system, etc.
- Construction of some plant buildings and structures under the supervision and control of the contractor.
- Oversight of component manufacturing in the domestic industry and abroad.
- Planning and co-ordination of O&M personnel.
- Emergency planning.

In general, it is advisable to define incentives for increased domestic participation. The inclusion of such incentives should constitute a fixed requirement in the BIS. Additionally, the price information should include the percentage of national supply and imported supply (mixed fabrication). Contractual risks should be identified and considered in the evaluation process. The incentives and expected percentages of domestic participation should be defined. In the bid evaluation, bonuses or penalties for the proposed domestic participation may indicate the importance of these activities. Conditions for the acceptance (or rejection) of the proposals for domestic participation should be given, especially the types of warranty needed to ensure that the proposed domestic participation in the execution of the work can be achieved.

Local manufacturing could be enhanced to a great extent by placing binding bulk orders, or at least having well-founded prospects for future orders, for a certain number of components. For that, a nuclear programme consisting of four to five NPPs could be the basis on which to encourage local manufacturers to expand their manufacturing capabilities to include a spectrum of new products. Consequently, the integration of nuclear energy into a country's energy system could be regarded as a long term effort in the case where a series of NPP projects are to be deployed to address the growing energy demands of the country.

Domestic participation in the first NPP and in the units following depends principally on the industrial infrastructures and engineering capability already existing. A comprehensive industrial survey in the owner's country must be performed before a detailed proposal by the supplier(s) and/or the A/E can be made. Additional investment(s) in the owner's country must be considered for hardware, software and personnel training, and must be in line with the national nuclear power planning and research and development programme.

A high level of technology and specific know-how are needed for most of the designs and for the production of components for an NPP. Furthermore, the existing capability and experience in the owner's country in plant construction have to be investigated and upgraded if necessary. Training programmes have to be established in various fields, particularly engineering and manufacturing, in order to help increase domestic participation.

An integral part of supply capability is the respective technology and know-how for design and manufacturing. If technological processes and quality assurance can not be applied from the country's own experience, these activities could become part of the technology transfer programme.

Domestic participation in an NPP could be achieved in the following areas:

- Civil works.
- Mechanical components and systems for:
  —Nuclear plant,
  —Conventional plant.
- Electrical components and systems.
- I&C.
- Nuclear fuel cycle.
- Engineering and project management.
- Erection and commissioning.

These activities are country specific and can only be implemented if the development and experience gained are expected to favour domestic participation in the following areas of nuclear projects:

Civil works. For the civil structures, especially for the nuclear buildings, high quality materials are required, such as high quality concrete and reinforcements. The quality and the capability of local civil constructors as well as the prices for materials and labour have to be analysed in detail. All technical data and information provided should be analysed in the technical bid evaluation process.

Mechanical components and systems. Depending on the capabilities of the local industry, a wide range of domestic participation is possible in the areas of mechanical equipment, components and structures. The technical evaluation process should concentrate mainly on the engineering, quality, materials and documentation.

I&C. The comments on mechanical components are also valid for I&C. In most developing countries, only a small percentage of domestic participation can be assumed for the first NPP project with respect to fabrication of electrical equipment for special applications in nuclear systems.

Nuclear fuel cycle. Domestic participation in the nuclear fuel cycle is in most cases connected with a long term programme. The investments necessary for the front end and back end of the fuel cycle are quite large. With respect to the budgetary requirements at the start of a nuclear power programme, only fuel assembly manufacturing and uranium dioxide (UO_2) production may be considered for domestic participation. The specialities of the various reactor types and their differences, particularly in the nuclear fuel cycle, have to be recognized. Prospecting for, and mining of, uranium may be undertaken by several countries supporting the nuclear power programmes. The investment for the necessary infrastructure is significant; therefore, the undertaking may need to be organized and implemented by several countries.

Engineering and project management. Domestic participation in the different areas of engineering and project management has to be assessed on the basis of available qualified staff in the owner's organization or country. Project management is possibly the most critical activity for successful project implementation. For the first NPP project, assuming full responsibility for the overall project management would constitute a very large workload. Consequently, a first unit could become a high risk project for a utility without sufficient experience in the nuclear field. With any type of contractual approach, the owner is directly or indirectly responsible for project control and supervision. Therefore, the owner has to set up its own project management organization, headed by an experienced project manager. The organization should be staffed with about 30–40 qualified professionals before the start of construction. In the case where a developing country starts its nuclear programme with a turnkey contract, the lead for project management should lie with the responsible supplier (design review and control, construction and erection supervision, equipment and component manufacturer supervision, plant commissioning supervision, etc.).

Project management is an essential activity for successful project implementation. The first task of the utility/owner's project management group concerns the performance of acquisition activities. These are as follows:

- Establishment of the organization and staffing;
- Completion of site qualification, including validation of the relevant data and information;
- Definition of contractual approach;
- Preparation of the BIS;
- Evaluation of bids;
- Selection of suppliers;
- Arrangements for financing;
- Negotiation and finalization of contracts.

After contract finalization, and depending on the contractual approach adopted, the main tasks are the following:

- Management of the owner's scope of supply,
- Co-ordination of quality assurance/quality control programmes and audits,

- Schedule control,
- Cost control,
- Compliance control of the supplier(s) with the contractual terms and conditions,
- Design review,
- Supervision of equipment and component manufacture,
- Supervision of construction and erection,
- Supervision of plant commissioning,
- Review and approval of O&M procedures and manuals,
- Management of overall project documentation,
- Management of the training of O&M personnel,
- Procurement of nuclear fuel and fuel cycle services,
- Licensing application and regulatory follow-up.

Assistance with some of these project management tasks may be obtained from an A/E or from the main contractor.

The establishment and implementation of a quality assurance programme for a nuclear power project are important. Quality assurance is an essential aspect of good management. Good management contributes to the achievement of quality by effecting a thorough analysis of the tasks to be performed, identifying the skills required, selecting and training appropriate personnel, using appropriate equipment, creating a satisfactory environment in which an activity is performed, and recognizing the responsibility of the individual who has to perform the task.

Erection and commissioning. The procedure to be followed for plant erection is heavily dependent on the capabilities already available in the owner's country. If the BIS requests a large programme for domestic participation, the 'supervisor erection model' may be applied. In this model, the main contractor and/or the A/E deliver(s) erection manuals and instructions for all equipment and systems to be assembled and erected. In addition, the main contractor and/or the A/E offer(s) some supervision in order to ensure the correct assembly of components and systems, in accordance with the erection manuals and the instructions contained therein.

The erection work may be executed by local companies under contract to the main contractor, or by the owner or by the A/E. The same model may be applied for the commissioning of the plant.

The selected model must be very carefully defined, especially with regard to the delegation of responsibility for the work and the project time schedule.

The major part of NPP commissioning covers a period of two or three years, from the completed erection of the first system to the date of commercial operation. Plant O&M personnel should participate in plant construction and commissioning.

The personnel should be either totally in charge or under the supervision of the main contractor or the A/E. The costs of this effort are to be charged to the owner. In general, the construction and commissioning phase provides an excellent opportunity for 'on-the-job' training of professionals, technicians and craftsmen.

8.4. ASSESSMENT OF TECHNOLOGY TRANSFER IN THE ECONOMIC BID EVALUATION

For technology transfer assessment, procedures need to be developed for comparing the offered proposals and to translate the results into cost figures, or if this is impossible, to obtain qualitative results. Agreement on the procedures must be reached within the evaluation team. The scope of technology transfer is mainly influenced by the type of contract selected.

For the first NPP, the turnkey approach, including technology transfer, is recommended. The owner should integrate its staff as early as possible into the various activity centres of the main contractor(s) or its manufacturer. The responsibility for all work remains with the main contractor.

By the time an owner is ready for an NI and CI contract (split package), there should be a sufficient number of qualified staff available. In this approach, technology transfer could be requested in a more specific or limited programme which could lead to cost savings. The limited and desired scope should be specified in the BIS.

For multiple package contracts, the owner and local industry should have already accumulated considerable experience. Thus, technology transfer would be rather limited, and this should be reflected in the BIS.

In the evaluation process, the experience of the different suppliers has to be analysed so that the reliability of the information provided can be assessed in a qualitative and/or quantitative form. The assessment and analysis of various divisions of technology transfer are discussed as follows.

8.4.1. Transfer of written documents

The comparison of the technical documents presented in the bids is a very difficult task and in most cases it is only possible on a qualitative basis. The desired scope of the documents requested and the conditions of the different activities, such as basic engineering, detailed engineering, design review, procurement, commissioning and erection, should be indicated in detail in the BIS. Because of the different characteristics of civil, mechanical, electrical and systems engineering, the specifications must define the spectrum of documents and the desired content which have to be transmitted within a technology transfer agreement. For evaluation purposes, the offered scope of documents has to be checked against the BIS. Additionally, the number of drawings, technical reports, calculations, descriptions, special loading reports, physical layout reports, licensing documents, fabrication documents, quality assurance requirements, etc., for the following areas have to be assessed and listed:

- Plant layout.
- Civil engineering.
- Mechanical and electrical engineering.
- Systems engineering for:
  —Nuclear systems and components,
  —Conventional systems and components
  —Electrical systems and components.
- I&C.
- Reactor protection system.
- Manufacturing.
- Construction and erection.
- Commissioning.
- Operation.
- Maintenance, repair work, in-service inspection.
- Nuclear fuel cycle.

Appendix II lists the various kinds of documents, specifications, reports, drawings, etc., that might be requested. The level of fulfilment of the BIS requirements as a percentage should be used for comparison in the evaluation.

8.4.2. Transfer of computer programs and data banks

Bids offering the transfer of computer programs and data banks can only be evaluated on a case by case basis. This can be done by studying the content of the offered computer programs and their adaptability to the local computer system. Therefore, a detailed description of the capability and the kinds of program, the subjects covered, the computer language and the methods of transfer is required. The different bids can be compared with the help of lists that summarize the program and the subjects covered. The training needs of the personnel handling the computer programs at the owner’s and/or the A/E’s computer centres should be clearly identified. This is important, because the transfer of programs without the training of personnel is in most cases ineffectual. The person-months for training should be listed and compared.

8.4.3. Assignment and delegation of personnel

The assignment and delegation of personnel to the owner's country for special purposes should be assessed in accordance with the requirements of the BIS, giving consideration to their respective qualifications. The periods of assignment may vary from a few months to several years.

8.4.4. Training of personnel

The training can be performed by the method of 'learning by doing', classroom training or field training. Field training would take place at the manufacturers' facilities, at the site during construction, commissioning and startup, and/or at a simulator (on-line or off-line). The trainees should be required to pass examinations to obtain formal certification. Certification will document competence and experience gained and will serve as a basis for trainees who have graduated to positions as shift personnel and assist their efforts to obtain an operator licence. Attainment of the operator licence is of great importance.

The scope of training should be specified in the BIS in order to receive comparable scopes of supply from all the bidders (person-months and the training documentation, such as manuals, reports, video tapes or disks, etc.).

The following aspects may be considered in the evaluation:

- Field of training,
- Qualification of trainer,
- Place and kind of training,
- Duration of training,
- Training materials,
- Pre-qualification of trainees.

The offered person-months and the degree of qualification should be assessed and, if possible, translated into cost terms. Further aspects should be evaluated qualitatively.

8.4.5. Research and development

In the context of technology transfer, research and development activities can be organized by research centres, industry groups or governmental authorities. In the BIS evaluation, this item can be handled on a very general basis, supporting the main aspects and activities of the nuclear power programme. The research and development activities offered should be listed for comparison and quantitative assessment.

8.4.6. Formation of new companies and organizations and upgrading of existing ones

Before deciding whether to establish new manufacturing facilities or engineering companies in a country, the existing organizations have to be carefully analysed as regards their ability for making on-time deliveries to an NPP. The investments that may be needed for new manufacturing equipment or for the update of existing facilities have to be assessed. A large investment can only be justified for a long term nuclear programme. Otherwise, the import of reactor components (classes 1 and 2) would be more economical than if a local manufacturer could be qualified for manufacturing the higher class, sophisticated equipment. The expected capabilities of other industries at home or abroad to market these products have to be checked on a realistic, reliable and economic basis. Many countries have overestimated the market demands and oversized their manufacturing capacities in comparison with the actual market demands.

The following organizations should be checked regarding their current capabilities and what minimum capital investment would be necessary for producing reactor or conventional components, other specific equipment and/or related services:

- Engineering companies;
- Manufacturers of mechanical equipment (nuclear and conventional);
- Civil works companies;
- Electrical equipment manufacturers;
- I&C manufacturers (possibly under a licence agreement);
- Governmental bodies for licensing of the site, the safety of the NPP, the construction, commissioning and startup of the plant.

In the analysis, all identified activities and efforts should be well documented and assessed in the bid evaluation report, such as:

- The type of industry for which improvements or new installations are proposed.
- The experience of the supplier, its technical capability and financial resources.
- The capital investment required in:
  —The owner's country,
  —The supplier's country.

8.4.7. Owner's scope

In some cases, it may be necessary to assist the owner at a very early stage of the project with regard to siting, basic engineering, project management, licensing, quality assurance, BIS preparation, etc. These activities may be offered either separately or inclusively, within the framework of a technology transfer proposal, for the work to be done during the project time. The evaluation can be quantitative (person-months) or qualitative and should reflect the offered scope of services.

8.4.8. Pre- and post-graduate education

It may be necessary to establish a pre- and/or post-graduate programme at technical high schools or similar institutions in the supplier's country. Normally, this starts with language training in the owner's country or abroad. These activities may be specified for a project already in its advanced stages or they may be handled through a bilateral agreement between countries. They may also be specified in the BIS. If different proposals are available, a comparison and evaluation should be performed.

8.5. CONCLUDING REMARKS

The wide range and complexity of technology transfer in the various areas of a nuclear power programme and the problems that may be encountered in an economic evaluation should be apparent from the above discussion. The evaluation team will have to use its experience as well as qualitative arguments in order to arrive at objective results. The results can be used to identify the qualitative and quantitative differences in the offers of the various bidders.

Appendix I

FURTHER CONSIDERATIONS ON EVALUATION METHODS

I.1. CRITERION BASED ON PAY BACK OR CAPITAL RECOVERY TIME

In general, the pay back time or capital recovery time T of an investment is defined by the equation:

$$\sum_{t=T_B}^{T}\left(R_t - C_t\right) = 0 \qquad (20)$$

where: T_B = reference date of bid T_B, but could also be another reference date after which expenditures begin
R_t = revenue cost stream
C_t = investment cost stream.

Figure 8 shows the cumulative cash requirements for the key periods during the project life of an NPP. Note that the pay back time should not be confused with the time for repayment of loans.

If the cost stream C_t is broken down into an investment I that is made at one point in time, and a variable cost F_t covering, for instance, fuel and O&M costs for a power plant, this equation can be written in the following form:

$$I = \sum_{t=T_O}^{T}\left(R_t - F_t\right) \qquad (21)$$

where: T = time required for net operational revenues to pay back the capital investment
T_O = date of commercial operation.

In accordance with this criterion, the best investments are those which have a shorter recovery period. The method is based on a policy of liquidity rather than on a policy of profitability. This procedure of evaluating and selecting investments is used especially in times of political and economic instability. However, ranking bids on the basis of this criterion ignores the benefits and costs that extend beyond the capital recovery date, and the method is often criticized as being ‘short-sighted’.

The main disadvantages of this method are:

- Time value of money is not considered
- Net cash flows after the pay back period are not considered.

I.2. CRITERIA BASED ON PRESENT WORTH VALUES

The most comprehensive of all present worth criteria are based on the ranking of alternatives according to their net discounted profits, i.e. according to the difference between the present value of revenues and the present value of costs.

I.2.1. Maximum net present worth of profits

The net cash flow Q_t at the time t of an investment is equal to the difference between the cash flow of the expected revenues R_t and the cash flow of the expected expenditures C_t.

The net cash flow during the period t can be expressed by:

$$Q_t = R_t - C_t \tag{22}$$

where: Q_t = net cash flow at time t
R_t = cash flow of the expected reserves
C_t = cash flow of the expected expenditures.

If the discount rate d is equal for all future periods of time, the net present worth of profits is given by the following formula:

$$\text{Net present worth} = \sum_{t=T_B}^{T_L} \frac{Q_t}{(1+d)^{t-T_D}} \tag{23}$$

where: d = discount rate
T_B = bid reference date
T_D = date to which discounting is performed (T_D will be T_B for bid evaluation purposes; in other contexts T_D may be the start of operation date T_O)
T_L = end of the economic life.

The cost accumulated until time T_L includes the discounted value of costs committed to be spent after T_L, in particular, the decommissioning cost.

Note that this formula assumes 'end of period' payments which are discounted to the beginning of the first period. It is clear that investments with a higher net present worth are preferable. The discount rate may be real or nominal, as appropriate.

Of the criteria discussed in Appendix I, the 'maximum net present worth of profits' criterion is one of the most widely applied.

I.2.2. Minimum present worth of total plant costs

If alternative projects offer identical services, i.e. an identical present worth of the expected revenues (R_t), the options may be compared on the basis of the present worth of the expected expenditures (C_t). The option with the lowest present worth of costs would be economically preferable.

The present worth of the total plant costs can be expressed by the formula:

$$\text{Present worth of total plant costs} = \sum_{t=T_B}^{T_L} \frac{C_t}{(1+d)^{t-T_D}} \tag{24}$$

where: C_t = cash flow of the expected expenditures in year t
T_B = bid reference date
T_D = date to which discounting is performed (T_D will be T_B for bid evaluation purposes; in other contexts T_D may be the start of operation date T_O)
T_L = end of the economic life.

I.2.3. Criterion based on internal rate of return (IRR)

The internal rate of return (IRR) of an investment with revenue and cost streams R_t and C_t respectively, is defined as the discount rate at which the net present worth becomes zero. The appropriate discount rate (IRR) can be obtained by the following equation:

$$\sum_{t=T_B}^{T_L} \frac{R_t - C_t}{(1+\text{IRR})^{t-T_D}} = 0 \tag{25}$$

Note the similarity of this equation (Eq. (25)) to Eq. (2) for the LDEGC when IRR is replaced by d and R_t by $C{\cdot}E_t$. In fact, it is the same formula and can be used in two different approaches:

- An appropriate discount rate is selected and the formula gives the electricity cost, such that if the kW·h is sold at this price the return on the investment will precisely equal the discount rate.
- The price at which the future kW·h can be sold is assumed and in this case the formula gives the resulting IRR (equal to the discount rate that would result in a generating cost equivalent to the considered selling price of electricity).

It will be of economic interest to commit only those investment projects whose rate of return, IRR, is greater than the discount rate established for the respective country/utility. First priority will be given to those investment alternatives whose IRR are the highest.

An advantage of this method is that the investments are ranked according to their yields, thus avoiding the use of externally established rates of return. However, it requires appropriate estimates of future costs and revenues, based on the projected electricity price.

I.2.4. Evaluation of projects for plant improvement

Projects for plant improvement (refurbishment, upgrading, life extension) can be evaluated using the same method as for new plants.

The net present worth of an improvement project is the present worth of its cash flow, which is calculated from its revenues and costs:

$$\text{Net present worth} = \sum_{t=0}^{L} \frac{E_t \times c_{e_t} - C_{a_t} - C_{o_t}}{(1+d)^t} \tag{26}$$

where:
- E_t = electricity generated in year t
- c_{e_t} = electricity selling price in year t
- C_{a_t} = differential cost in year t
- C_{o_t} = other costs in year t
- d = discount rate.

The IRR is defined as the discount rate at which the net present worth becomes zero:

$$\text{Net present worth} = \sum_{t=0}^{L} \frac{E_t \times c_{e_t} - C_{a_t} - C_{o_t}}{(1+\text{IRR})^t} = 0 \tag{27}$$

The IRR can be calculated iteratively by varying the assumed discount rate until the net present worth becomes zero.

I.3. CONSTANT VERSUS CURRENT MONEY EVALUATION

Essentially, the economic ranking of the bids will not be affected by the choice of levelized generation costs expressed in the constant money of a reference year or in current money. So both approaches are possible, although, more generally, the interpretation that can be made of them is different, as is shown below:

Levelized costs in **constant** money	Levelized costs in **current** money
• Provides clear picture of cost trends • Levelized values appear close to current values, ensuring an easier understanding of the figures	• Inflation effects obscure real cost trends • Levelized values appear higher than current values (but close to business plan values)

In the case of an economic bid evaluation, the financial dimension (loan proposals) should be included. Since loan conditions always refer to current money (interest rates include inflation), the TCIC (discounted value of all investment expenditures including loan repayments) can only be determined through a current money computation.

It can be seen from the mathematical expression that the discounted value of costs occurring at different times and expressed in current money is automatically expressed in constant money of the date to which the discounting is made.

Should the discounting date be the bid reference date, all costs (capital, O&M, fuel), even if expressed in current money, will have their discounted figure expressed in constant money of the bid reference date. However, if the date to which discounting is made is the start of commercial operation (T_o), the discounted figures will be expressed in money of that specific year.

The option of having levelized generation costs expressed in constant or in current money relates to the way energy is discounted. If the nominal discount rate is used, the levelized generation costs will be expressed in current money (mixed years of commercial operation period). If the real discount rate is used, the levelized generation costs will be expressed in constant money of the reference date for discounting (bid reference date).

Table IX summarizes the above considerations.

TABLE IX. LEVELIZED GENERATION COSTS VERSUS ECONOMIC PARAMETERS

Item	Cost nature	Escalation	Interest rate	Discount rate	Result (PW value)	Equation
Investment, fuel cost, O&M cost	Cost expressed in constant money of a reference year (generally the bid reference year)	Real value	Real value	Real value	A1 Expressed in constant money of reference year	Numerator of (Eq. (3)) with $d=d_r$
	Cost expressed in current money	Nominal value	Nominal value	Nominal value	A2 Expressed in constant money of the discounting date	(Eqs (8–10))
Electricity generation (kW·h)		Not applicable		Real value	B1 Straightforward generation of PW value	Denominator of (Eq. (3)) with $d=d_r$
				Nominal value	B2 Discounting with nominal discount rate reduces the PW value	Denominator of (Eq.(3)) with $d=d_n$

I.4. PROJECTION OF FUTURE CURRENCY EXCHANGE RATES

In estimating future variations in currency exchange rates, risks and uncertainties will have to be considered. The inflation rate within a country influences the purchasing power for materials and services. In the long term, the relative inflation among countries will, to a large extent, determine the exchange rates. It is emphasized that exchange rate variations can have a very considerable effect on international cost comparisons. The apparent cost relations for a given bid can be reversed merely by adopting a different base date for the comparison. This is a consequence of movements in exchange rates which often fail to parallel the rates of domestic inflation.

The forecasting of exchange rates is highly speculative since these rates are influenced not only by economic factors (inflation and interest rates) but also by sociopolitical factors.

In the absence of better information on exchange rate forecasts, one method that may be employed in the assessment of exchange rates is based on the theory of 'purchasing power parity' (PPP), which is described briefly below. This theory points out the linkage of exchange rate variations with the price levels of comparable goods and services expressed in the corresponding currencies. The PPP theory maintains that the exchange rates move between two countries in such way that the terms of trade (the price of exports relative to imports) are kept constant. The movement is primarily a result of differences in price level behaviour. The theory argues that exchange rate movements primarily reflect divergent inflation rates.

The PPP theory gives a plausible explanation of the trend behaviour of exchange rates, especially when the inflation differentials between countries are large. If price level movements are caused by monetary changes — as is likely if the inflation rate is high — the PPP theory is expected to hold in the long term. However, exchange rates tend to move quite rapidly relative to prices, and thus in the short term (3–12 months) the actual exchange rates may deviate substantially from the rates calculated by using the PPP theory. Moreover, disturbances other than monetary ones also affect exchange rates. For example, an increase in exports improves the terms of trade or leads to currency appreciation with domestic prices remaining unchanged. Empirically, the views regarding exchange rates laid down in the PPP theory work well when inflation differences predominate. However, not all exchange rates are caused by monetary disturbances. Additionally, the PPP theory does not provide a good explanation for the short term behaviour of exchange rates.

I.4.1. Levelized generation cost

With reference to Table IX:

A1/B1: Generation cost expressed in constant money of reference date (generally bid reference date). This type of calculation is used by the OECD Nuclear Energy Agency and by the Union internationale de producteurs et distributeurs d'énergie.

A1/B2: Not used.

A2/B1: Generation cost expressed in constant money of the discounting date. This approach is recommended in this report and is implemented in the software BIDEVAL-3.

A2/B2: Generation cost expressed in mixed year currency of commercial operating period and also calculated in the software BIDEVAL-3.

For the definition of real and nominal escalation, interest and discount rates, see Section 5.4 and the Glossary.

Consider two currencies, *A* and *B*, where *A* is the reference currency, with an exchange rate $E_{A/B}$ to the reference currency known at time t=T_R. Assume a cash flow stream as in currency *B*, either from direct payment or from financial arrangements, at time *t*. The present worth of the payment at the reference date T_R is:

$$PW = \sum_{t=T_R}^{T_L} C_{B_t} \times E_{A/B} \times \alpha_{A/B_t} \times \frac{1}{\left(1+d_{nA}\right)^{t-T_R}} \qquad (28)$$

where:
- T_L = end of study period or economic life
- T_R = reference date (the time at which the exchange rate to the reference currency is known)
- $E_{A/B}$ = exchange rate to the reference currency
- C_{B_t} = cash flow stream in currency *B* at time *t*
- α_{A/B_t} = exchange rate conversion coefficient
- d_{nA} = nominal discount rate of currency *A*.

According to the PPP theory, the exchange rate conversion coefficient may be expressed as:

$$\alpha_{A/B_t} = \frac{\left(1+e_{iA}\right)^{t-T_R}}{\left(1+e_{iB}\right)^{t-T_R}} \qquad (29)$$

In Eq. (29), e_{iA} and e_{iB} are the inflation rates for currencies *A* and *B*, respectively. Thus, the present worth of the cash flows may be written as:

$$PW = E_{A/B} \times \sum_{t=T_R}^{T_L} C_{B_t} \frac{(1+e_{iA})^{t-T_R}}{(1+e_{iB})^{t-T_R}} \times \frac{1}{(1+d_{nA})^{t-T_R}} \tag{30}$$

The nominal discount rate of currency A is given by:

$$(1 + d_{nA}) = (1 + d_r)\,(1 + e_{iA}) \tag{31}$$

where: d_r = real discount rate set by the owner and common to all currencies.

The present worth of the cash flows then becomes:

$$PW = E_{A/B} \times \sum_{t=T_R}^{T_L} C_{B_t} \times \frac{1}{\left[(1+d_r)(1+e_{iB})\right]^{t-T_R}} \tag{32}$$

This is independent of the inflation rate of the reference currency A.

In order to minimize the uncertainties of this procedure, the official publications of an international body, for instance the OECD or the International Monetary Fund, should be used as a common reference for the exchange and inflation rates. When the same values for the relevant parameters are used, this method will lead to the same result as the recommended method (Section 5, Eqs (14) and (15)).

The effect of the exchange rate estimates on the economic bid evaluation should be thoroughly analysed in several ways. For instance, an alternative calculation could be made using constant exchange rates for currencies with only slightly different inflation rates.

I.5. COST ALLOCATION METHODS FOR CO-GENERATION PLANTS

The cost allocation methods that have been used for the co-generation of electricity and heat or potable water can be split into two main groups: cost prorating methods and credit methods (see Table X). The credit methods attribute a value to one of the products and obtain the cost of the other by difference. This value could be based either on market conditions or on production costs of single purpose plants. The cost prorating methods divide the overall expenditures of the integrated plant according to a given set of rules entailing, in general, a sharing of the benefit of co-production between the two final products.

The following discussion refers to the co-generation of electricity and potable water. The same logic would apply for the co-generation of electricity and process heat or district heat.

TABLE X. COST ALLOCATION METHODS FOR CO-PRODUCTION OF POTABLE WATER AND ELECTRICITY

Credit methods	Cost prorating methods
Credit method based on market conditions	Proportional value method
Power credit method	Caloric method
Water credit method	Exergetic method

The credit method based on market conditions allocates a market oriented value to one of the products (electricity or potable water) and determines the cost of the other by subtraction from the overall cost of the integrated plant.

The power credit method is based on the concept that the electricity equivalent of steam supply (electricity that could have been generated by the steam supplied to the distillation plant) and/or electricity provided to the seawater desalination plant could have been sold to the grid, and that this loss in revenue should be charged to the water cost (power credit). The power credit is calculated by multiplying the reduction in electrical output by the unit electricity generation cost of an equivalent single purpose power plant. Applying the power credit method, the potable water produced is credited with all the economic benefits associated with co-production.[3]

In the water credit method, the whole benefit of co-production is assigned to the cost of the electricity by using a water credit, the value of which would be equal to the cost of water produced in an alternative least cost water scheme.

In the proportional value method, either the market values of the two products or the production costs of two single purpose plants are determined. The first produces the same quantity of potable water, and the other supplies the same net amount of electricity to the grid, as the integrated plant. The overall cost of the integrated plant is then divided in proportion to the ratio of the values or costs of the two individual products so defined and then allocated to the electricity and potable water respectively.

The caloric method is based on the First Law of Thermodynamics (law of energy conservation). The method allocates the common production costs of the power station in proportion to the amount of enthalpy used to produce electricity and low temperature steam for the seawater distillation plant respectively.

[3] INTERNATIONAL ATOMIC ENERGY AGENCY, Technical and Economic Evaluation of Potable Water Production Through Desalination of Seawater by Using Nuclear Energy and Other Means, IAEA-TECDOC-666, IAEA, Vienna (1992).

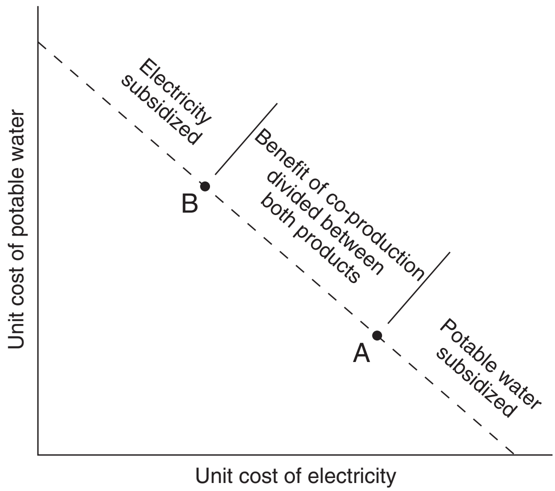


FIG. 16. Qualitative example of the electricity generation and potable water production cost allocation of an integrated plant.

Figure 16 shows the qualitative relationship between the electricity generation and potable water production costs of an integrated plant obtained by the various cost allocation methods described above. To share the benefit of co-production of electricity and potable water, the cost allocation method chosen should result in points located somewhere inside the line segment A–B in Fig. 16.

Note that points obtained with the proportional value method and the credit method based on market conditions could be anywhere on the line, depending on market values.

The exergetic cost allocation method uses energy prorating. It assigns thermodynamically appropriate values to the steam supplied to the turbine generator unit and to the heat delivered to an external facility. The method allocates the costs according to these thermodynamically appropriate values.

The water credit method and the power credit method have the disadvantage that one of the final products has no share in the benefit.

The disadvantage of both the proportional value method and the credit method based on market conditions is that only market oriented criteria are considered. Therefore, the thermodynamic capability of the integrated plant in producing electricity and potable water is not covered adequately.

The caloric method covers some of the process specific thermodynamic criteria of the integrated plant. However, there is no adequate assessment of the thermodynamic value (exergy) to be assigned to the energy flows required to produce electricity and potable water.

From the thermodynamic viewpoint, as well as considering the sharing of the benefit, the exergetic cost allocation method is the most equitable one. This method is extensively described in a recent IAEA publication.[4]

The choice of the cost allocation method will largely depend on the specific situation of the utility, in particular on the markets for electricity and heat or water. In practice, the power credit method is widely applied, not least because it is relatively simple and straightforward.

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[4] INTERNATIONAL ATOMIC ENERGY AGENCY, Thermodynamic and Economic Evaluation of Co-production Plants for Electricity and Potable Water, IAEA-TECDOC-942, IAEA, Vienna (1997).

Appendix II

LIST OF TYPICAL BID DOCUMENTATION

1. Documentation for an NPP bid

1.1. General information
- Legal and commercial documentation
- References
- Experience and qualification of the bidder
- List of main subcontractors
- Overall project schedule and scope of supply
- Summary of technical description
- Organization of the project
- Deviation and exceptions

1.2. General technical aspects
- Design
- Construction and commissioning
- O&M
- Safety and licensing
- Documentation

1.3. Technical description of NI
1.4. Technical description of nuclear fuel and fuel cycle
1.5. Technical description of TG plant system
1.6. Technical description of BOP
1.7. Technical description of electrical systems
1.8. Technical description of I&C
1.9. Technical description of civil works
1.10. Spare and wear parts, consumables and special tools
1.11. Scope of services
1.12. Alternatives and options
1.13. Project construction schedule
1.14. Quality assurance programme
1.15. Training
1.16. National participation and technology transfer
1.17. Guarantees and warranties
1.18. Commercial conditions

2. Documents for overall plant engineering

- Project implementation and control system
- Plant descriptions
- Power station code and application methods
- Time schedule
- Work reports, containing:
  - Calculations (stress analysis, fatigue analysis, etc.)
  - Design (memos/reports)
  - Loads and special loads, component loads
  - Piping loads
  - Valve loads
  - Engineering (memos)
  - Seismic analysis
  - Floor response spectra
  - Power balances
  - Safety proofs
  - Thermal cycle calculations
- Technical reports, containing:
  - Feasibility studies for foundations
  - General description of the arrangement of the primary system
  - General instructions and requirements for system engineering
  - General commissioning execution instructions
  - Procedure classification and definition of safety related equipment and systems into quality categories
- Quality assurance programme
- Governmental guidelines
- National standards
- International codes and standards (as applicable)
- Qualification procedures and general audit report for equipment suppliers and erection companies
- Quality specifications:
  - Design specification
  - Component specification
- Quality requirements:
  - Material specification
  - Process specification
- Technical conditions
- Additional requirements
- List of spare and wear parts
- Preliminary safety analysis report

- Final safety analysis report
- Supporting documents for licensing purposes
- Computer codes
- Technical reports concerning nuclear and thermal-hydraulic core design
- Thermal-hydraulic design report, containing:
  - Thermal-hydraulic core design
  - Design data
  - Investigations concerning thermal-hydraulic core design, including thermal-hydraulic fuel assembly testing
- Transient analysis report, containing:
  - Reactivity accidents
  - Disturbances of heat removal with loss of coolant
  - Reactivity effects from loss of coolant accidents in the secondary system
  - Reactivity effects from loss of coolant accidents in the primary system
- Neutron physics design report, containing:
  - Nuclear design calculations for fuel assemblies
  - Critical boron concentration and xenon reactivity
  - Efficiency of the shutdown systems
  - Reactivity coefficients
  - Burnup calculations
  - Power density distribution
  - Power statistics
  - Procedure for the first core loading
  - Subcriticality during the first core loading
- Fuel management:
  - Long term general refuelling schemes (these schemes do not include an optimization of the refuelling schemes to the limits of fuel rod and thermal-hydraulic design)
  - Description of methods for measurement of:
    * Critical boron concentration
    * Boron equivalent of control assembly groups
    * Three dimensional power distribution and hot channel factors for normal control assembly configuration

3. Documents for civil engineering

- Design criteria report
- Site plan
- Axis plan
- Architectural basic design drawings
- Overall perspective drawing

- General data for civil structures
- Description of civil structures
- Basic dynamic analysis of safety related structures
- Basic dimensions of the main structural parts
- Global load distribution
- Special load summary list
- Steel platform concept and arrangement plans
- Basic structural analysis of steel platforms
- Catalogue/drawings for anchoring devices
- Basic building plans with related lists of built-in parts
- Load plans
- Fire protection plans
- Basic sanitary building installation drawings
- Foundation report
- Licensing documents
- Site installation area plan
- Time schedule for engineering activity sequence
- Time schedule for construction
- Time schedule for finishing work planning
- Time schedule for finalizing work
- Structural analysis
- Dynamic analysis
- Vibration analysis of spring supported foundations (if any)
- Waterproofing drawings
- Architectural drawings of elevation of buildings
- Door position plans
- Door lists
- Structural analysis of stages of construction
- Road and rail arrangement plans
- External water and sewage plan
- Floor response spectra and floor time history
- Bill of materials for preliminary and finishing work
- Construction stage plan
- Lightning protection plans
- Measurement plans for survey of structures
- Finishing work plans for buildings and structures
- List of colours
- Evaluation report on soil data analysis
- Evaluation report on hydrological data
- Preliminary hydraulic calculations (steady state and transient)
- Preliminary thermal recirculation check

- Final hydraulic calculations
- Final thermal recirculation check
- General arrangement plans
- Formwork drawings with related lists for built-in parts
- Reinforcement drawings with associated rebar lists

4. Documents for plant layout engineering

- Concept plans
- Loads for the draft structural analysis
- General arrangement plans
- Room lists
- Load plans and data handbook
- Drainage system plans (nuclear part)
- Fire protection plans
- Radiological contingency plans
- Placement and foundation plans
- Transport and erection plans
- Plans and lists for small lifting equipment
- Plans for penetration sleeves through the containment
- Standard details for embedded parts
- Embedded part lists
- Steel structure and arrangement plans
- Site plan with mechanical and electrical locations
- Overall anchoring plans
- Anchoring lists, load action lists
- Arrangement plans for setdown areas
- Time schedule for engineering
- Regulations and rules for engineering or CAD
- Finishing work plans and data sheets

5. Documents for mechanical engineering (NSSS, NI)

- Arrangement and foundation layout plans
- Outline drawings
- System flow diagrams
- Piping and air duct layout drawings
- Isometric drawings (CAD)
- Valve lists, valve catalogue

- Support catalogue
- System descriptions
- Anchoring plans
- Component lists
- Design data sheets
- Piping list, piping catalogue
- Calculations
- Stress analysis as applicable
- Manufacturing documents (according to specifications):
  - — Drawings
  - — List of material
  - — Weld location list
  - — Inspection plan
  - — Welding plan
  - — Material testing and sampling plan
  - — Heat treatment plan

6. Documents for electrical engineering (NSSS, NI)

- Connection lists
- Arrangement drawings
- Function diagrams
- Lists (consumers, feeder data sheet, etc.)
- Circuit diagrams
- Data sheets
- Block diagrams
- System description
- Summary of data
- Load balance of auxiliary and emergency power supply
- Short circuit and voltage drop calculation
- Test plan
- Cable catalogue
- Cable layout drawings
- Single line diagram
- Layout drawings
- List of loading points
- Terminal diagrams
- List of equipment
- Design drawings
- Dimensional drawings

7. Documents for I&C engineering (NSSS, NI, TG)

- System description
- Description of reactor control system
- Description of reactor limitation system
- Description of reactor protection system
- Block diagrams
- Logic diagrams/functional diagrams
- Orifice data sheets
- Measuring and control data file
- Alarm signal data file
- Control desk layout
- Sensor installation drawings
- Equipment data sheets
- Standard connection diagrams
- Layout of cabinets
- Measuring transducer rack configuration
- Module arrangement drawings
- Equipment allocation list
- Junction box connection diagram
- Marshalling tables
- Connection list of cables
- Circuit wiring diagrams
- Main control room design
- Operating desk design

8. Documents for construction, erection and commissioning engineering (NSSS, NI)

- Quality assurance requirements
- Guidelines for site
- Fire protection handbook
- First aid/emergency handbook
- Site regulations
- Construction instructions (NSSS)
- Construction guidelines (NSSS)
- Construction work sheets (NSSS)
- Civil work standards handbook
- Erection instructions (NSSS)
- Quality assurance/quality control during commissioning

- Regulations for construction and erection, and acceptance procedure for commissioning
- Commissioning documents for NI and BOP, consisting of:
  - — Commissioning organization structure
  - — Commissioning work sheets (equipment and component testing)
  - — Commissioning time schedule
  - — Commissioning programmes
  - — Commissioning instructions
  - — Commissioning result reports and records
- Operation manual, consisting of:
  - — System startup and shutdown procedure
  - — Plant startup and shutdown procedure
  - — Comprehensive system descriptions with system flow diagrams
  - — Set points list
  - — Alarm list

9. Documents for fuel assembly engineering

9.1. Fuel assembly, control assembly, neutron source assembly and flow restrictor documents:
- Items list
- Manufacturing drawings and specifications
- Technical reports
- Design reports
- Data sheets
- Compatibility reports
- Information about methods and procedures
- Supporting engineering information
- Handling descriptions

9.2. Fuel assembly inspection, and shipping and repair facility documents:
- Document lists
- Specifications
- Drawings
- Technical reports
- Design reports

9.3. Shipping container documents for unirradiated fuel assemblies:
- Basic calculations, parameters and design criteria
- Design specification
- Drawings and part lists
- Qualification reports

- Licensing criteria and information by authorities
- Acceptance report

10. Manufacturing documents

- Planning document, containing information on how to fulfil technical requirements
- Requirement lists
- Technical requirements specification
- Electrical block diagram
- Design sketches
- Systems flow diagrams
- Electrical circuit diagrams
- Technical drawings draft
- Executive drawings
- Detail drawings
- CAD drawings
- Assembly drawings
- Procurement drawings
- Erection and construction drawings
- Design and manufacturing drawings
- Components list for standardized equipment
- Material, manufacturing and test specification
- Process specifications
- Design calculations
- Welding and welding test plans
- Material test plans
- Heat treatment plans
- Manufacturing quality documentation
- Construction guidelines
- Construction and erection plans and manuals
- Commissioning documents and instructions
- Operating manuals

Annex I

IAEA ACCOUNT SYSTEM
FOR NUCLEAR POWER PLANTS

This account system was prepared in order to provide assistance in checking the completeness of bids and in evaluating the total plant costs. The system is presented in the form of an illustrative example. Other systems of cost accounts exist which could also be used. The account system as described is sufficiently flexible as to allow different reactor types to be considered. It is also adaptable, so that it suits the particular requirements of the owner as well as the supplier.

The base costs that should be listed under account 21 include all the costs of the buildings and structures, including the bulk materials and the associated engineering and documentation for construction work at the site.

Accounts 22–27 include the costs of equipment manufacture, the cost of materials for components and systems, as well as the costs of engineering and documentation associated with the manufacturing process in the factory. If appropriate, the pre-installation assembly/site fabrication costs of some of the main components at site are included in accounts 22 and 23.

General site construction, installation labour and supervision costs may be included in accounts 34–39, as appropriate.

This account system is the one used in the computer software package described in Annex II. Changes in the account system made to satisfy particular applications can be easily incorporated in the computer program.

TOTAL CAPITAL INVESTMENT COSTS

Base costs

21 Buildings and structures at the plant site

211 Site preparation, facilities, infrastructure

.1 Land reclamation, clearing and grading
.2 Access roads, sidewalks, access roads connected with public roads
.3 Railway access
.4 Sanitary installations, yard drainage
.5 Storm sewer systems, waterfront structures

.6 Harbour and cranes, waterway improvements
.7 Air access facilities
.8 Fences, gateways, security installations
.9 Other infrastructures

212 Reactor building (materials)

All materials related to the structure in which the nuclear reactor is placed

.1 Excavation, backfilling and all related work
.2 Foundation, such as plates, piles, caissons, substructure concrete and other materials
.3 Superstructure, including inner and outer concrete structures, other inner structures, structural steel and other materials
.4 Special shielding inside reactor buildings isolated from normal concrete walls and not an integral part of components
.5 Building service systems, insofar as they form an integral part of civil works (see account 26)
.6 Cable and pipe ducts connecting the reactor building with other buildings
.7 Containment, i.e. free standing steel containment, liner, caissons, ice condenser; airlocks for personnel, materials or emergency; and pipe and cable penetrations are included

213 Reactor auxiliary building

.1 Excavation, backfilling and all related works
.2 Foundation, such as plates, piles, caissons, and substructure concrete and other materials
.3 Superstructure, including inner and outer concrete structures, other inner structures, structural steel and other materials
.4 Special shielding, such as movable walls which are not integral parts of components
.5 Building service systems, insofar as they form an integral part of civil works (see account 26)
.6 Cable and pipe ducts connecting the reactor auxiliary building with other buildings

214 Turbine building

The structures to be accounted are similar to those mentioned under 213, as applicable.

215 Electrical building

The structures to be accounted are similar to those mentioned under 213, as applicable.

216 Other buildings

Buildings that may be included are:

.1 Fuel storage building
.2 Radioactive waste treatment and storage buildings (radwaste building)
.3 Emergency diesel generator building
.4 Water treatment building
.5 Administration building
.6 Control building
.7 Information centre
.8 Service building
.9 Switchgear building
.10 Security building

217 Structures for transformers

218 Stacks (when separate from buildings)

22 Reactor plant equipment

221 Reactor equipment

.1 Reactor vessel
  .11 Reactor vessel and accessories
  .12 Closure head and attachments
  .13 Studs, fasteners, seals and gaskets
  .14 Calandria tubes and fittings
  .15 Pressure tubes and fittings
  .16 Insulation
  .17 Tools (stud tensioning device), accessories and handling equipment
.2 Reactor vessel internals (excluding fuel assemblies, reflector materials, moderators and reactivity control components)
  .21 Core tank or barrel container or moderator tank
  .22 Core baffles, core shrouds, distributors, orifices, throttles and strainers
  .23 Upper core structure

.24 Control rod guide assemblies
.25 Feedwater distributor
.26 Steam separators and driers
.27 Guides, channels, holders, etc., for irradiation specimen
.28 Tools, accessories, handling and storage equipment

.3 Reactor vessel support structures
.31 Reactor pressure vessel supports, brackets, sealings, pipe supports or others, including shielding materials if they are integral parts of the support structure

.4 Reactor control devices and other core installations
.41 Control rod drive mechanism (magnetic, hydraulic, motor driven, others)
.42 Control assemblies, drive shafts, etc.
.43 In-core instrumentation (mechanical equipment)
.44 Primary and secondary neutron sources
.45 Burnable poison (if not an integral part of the fuel)
.46 Boron fast shutdown system (for boric acid see account 27)

.5 Moderator system excluding moderator/reflector materials
.51 Piping
.52 Valves and fittings
.53 Supports (piping related)
.54 Insulation
.55 Circulation pumps, including motors, supports, fixtures
.56 Tanks, including supports, fixtures
.57 Heat exchangers

222 Main heat transfer and transport system

.1 Reactor coolant system
.11 Main coolant piping for guiding the main coolant between reactor pressure vessel, calandria, main coolant circulation pumps and steam generators
.12 Valves and fittings, including loop isolation valves (if present)
.13 Supports (piping related)
.14 Insulation
.15 Main coolant circulation pumps with motors and all necessary cooling, lubrication, and other auxiliary systems, support structures, special tools, service equipment, etc.
.16 Steam generators, completely assembled (U-tube, once-through vessel type) with support structures, brackets, sealings, fixtures
.17 Special service equipment, tools, cranes, in-service inspection installations, etc.

.2 Main feedwater line and main steam line up to the containment anchor point
  .21 Piping
  .22 Valves and fittings, including isolation, safety and relief valves in main steam line and feedwater line
  .23 Supports (piping related)
  .24 Insulation
.3 Pressurizing system
  .31 Piping
  .32 Valves and fittings
  .33 Supports (piping related)
  .34 Insulation
  .35 Pressurizer
  .36 Pressurizer relief tank
  .37 Cooling equipment
  .38 Pump for pressurizer relief tank

223 Reactor auxiliary systems

.1 Volume control system, seal water supply system for main coolant pumps
  .11 Piping
  .12 Valves and fittings, control valves with annunciator, and magnetic, check, isolation and other special valves
  .13 Supports (piping related)
  .14 Insulation
  .15 Charge pumps, including motors, supports, fixtures
  .16 Tanks, including supports, fixtures
.2 Boric acid and demineralized water supply system and chemical control system
  .21 Piping
  .22 Valves and fittings
  .23 Supports (piping related)
  .24 Insulation
  .25 Pumps, including motors, supports, fixtures
  .26 Tanks, including supports, fixtures
.3 Coolant purification system
  .31 Piping
  .32 Valves and fittings
  .33 Supports (piping related)
  .34 Insulation
  .35 Pumps, including motors, supports, fixtures
  .36 Tanks, including supports, fixtures

.37 Ion exchanger

.4 Coolant degassing system

.41 Piping

.42 Valves and fittings

.43 Supports (piping related)

.44 Insulation

.45 Pumps, including motors, supports, fixtures

.46 Heat exchangers, cooler, including supports, fixtures

.47 Degassification column, heater, including supports, fixtures

.5 Coolant storage and treatment system

.51 Piping

.52 Valves and fittings

.53 Supports (piping related)

.53 Insulation

.55 Pumps, including motors, supports, fixtures

.56 Tanks, including supports, fixtures

.57 Ion exchanger

.58 Heat exchangers, coolers, heater, condenser, including supports, fixtures

.59 Evaporator columns, including supports, fixtures

.6 Nuclear component cooling system

.61 Piping

.62 Valves and fittings

.63 Supports (piping related)

.64 Insulation

.65 Pumps, including motors, supports, fixtures

.66 Tanks, including supports, fixtures

.67 Heat exchangers, including supports, fixtures

.7 Fuel pool cooling and cleaning system

.71 Piping

.72 Valves and fittings

.73 Supports (piping related)

.74 Insulation

.75 Pumps, including motors, supports, fixtures

.76 Tanks, including supports, fixtures

.77 Ion exchanger

.78 Heat exchangers, including supports, fixtures

.8 Residual heat removal and emergency core cooling system

.81 Piping

.82 Valves and fittings

.83 Supports (piping related)

.84 Insulation
.85 Pumps, including motors, supports, fixtures
.86 Accumulator, including supports, fixtures
.87 Heat exchanger, including supports, fixtures
.9 Other safety systems

For other reactor types (BWR, PHWR, etc.), the respective auxiliary systems may be introduced in this account instead of the systems listed above as an example.

224 Reactor ancillary systems

.1 Liquid waste storage and processing system
.11 Piping
.12 Valves and fittings
.13 Supports (piping related)
.14 Insulation
.15 Pumps, including motors, supports, fixtures
.16 Tanks, including supports, fixtures
.17 Ion exchanger
.18 Heat exchanger, including supports, fixtures
.19 Evaporation columns, filter traps, separators, including supports, fixtures
.2 Gaseous waste processing system
Besides waste gas processing, this system also includes the normal circulation of inert gas inside the nuclear island water systems.
.21 Piping
.22 Valves and fittings, control valves with annunciator, and magnetic, check, isolation and other special valves
.23 Supports (piping related)
.24 Insulation
.25 Pumps, compressors, blowers, including motors, supports, fixtures
.26 Tanks for storage, buffering, including supports, fixtures
.27 Heat exchanger, coolers, heaters, including supports, fixtures
.28 Recombiners, dryer columns, activated charcoal beds, cold traps, silica gel beds, including supports, fixtures
.3 Radioactive waste processing system
(solidification of low and medium level radioactive waste inside the plant)
.31 Piping
.32 Valves and fittings
.33 Supports (piping related)
.34 Insulation

.35 Filling and drumming station
.36 Cement mixing and handling equipment, including supports, fixtures
.37 Bitumen mixing and handling equipment, including supports, fixtures
.38 Tools, rails and other necessary equipment, including supports, fixtures

.4 Nuclear component drain and vent systems
.41 Piping
.42 Valves and fittings
.43 Supports (piping related)
.44 Insulation
.45 Pumps, including motors, supports, fixtures
.46 Filters, sieves, traps, including supports, fixtures

.5 Nuclear building drain system
.51 Piping
.52 Valves and fittings
.53 Supports (piping related)
.54 Insulation
.55 Pumps, including motors, supports, fixtures
.56 Filters, sieves, traps, buffer tanks, including supports, fixtures

.6 Nuclear sampling system
.61 Piping
.62 Valves and fittings
.63 Supports (piping related)
.64 Insulation
.65 Tanks, including supports, fixtures
.66 Other special installations

.7 Hydrogen monitoring system
.71 Piping
.72 Valves and fittings
.73 Supports (piping related)
.74 Insulation

Special measuring equipment should be calculated under account 24.

For other reactor types (BWR, PHWR, etc.), the respective ancillary systems may be introduced in the account system instead of the systems listed above as an example.

225 Nuclear fuel handling and storage systems

.1 New fuel storage and inspection facilities
.11 Storage racks, supports, hangers, fixtures

.12 Manipulation and inspection tools and installation
.13 Fuel casks (if any)
.2 Fuel assembly loading machine inside and/or outside the reactor building
.21 Loading machine bridge(s)
.22 Manipulating mast for fuel assemblies and control rods from loading machine
.23 Other tools for handling or manipulation of fuel assemblies, control rods, core inserts, neutron sources, etc.
.3 Spent fuel storage pool inside and/or outside the reactor building
.31 Storage racks, compact racks
.32 Pool lining material, sluice gates, inserts, supports, leak control system
.33 Transfer locks and respective installations
.34 Tilter with fuel assembly drying system
.35 Supports, hangers, consoles for core components
.36 Sipping equipment
.37 Fuel assembly repair equipment
.38 Other handling installations, casks for damaged fuel assemblies, etc.
.4 Cask pool inside or outside the reactor building
.41 Cask support and protection equipment
.42 Pool lining material, sluice gates, dumper, shock absorber, set down equipment
.43 Decontamination equipment for fuel cask
.5 Spent fuel pool cleaning and cooling system (if not accounted under 223.7)

226 Other reactor plant systems and components

Under this account, all systems and components not mentioned in other accounts may be listed.

23 Turbine generator plant equipment

231 Turbine plant

.1 High pressure and low pressure turbines
.2 Turbine drain system
.3 Seal steam/leak off system
.4 Moisture separator/reheater system
.5 Turbine bypass system
.6 Lubrication and control fluid system
.7 Ancillary equipment such as speed controller, main stops, throttles, valves, gland seals, turning gear, piping, insulation, panel boards and

instrumentation which forms an integral part of the turbine generator, and protective devices, special tools, rotor lifting slings, shielding, etc.

.8 Support structures, turbine generator foundation (no concrete), mechanical parts (spring foundation, plates, fixtures, etc.)

232 Generator plant

.1 Generator
.2 Water system
.3 H_2 system
.4 CO_2 system
.5 N_2 system
.6 Lubrication system
.7 Seal oil system
.8 Excitation system
.9 Other auxiliary installations

(Support structures, valves, cable connections, etc.)

233 Condensate systems

.1 Main condensate system
  .11 Piping
  .12 Valves and fittings
  .13 Supports (piping related)
  .14 Insulation
  .15 Main condensate pumps, including motors, supports, fixtures
  .16 Condensate storage tank, including supports, fixtures
  .17 Condensate heaters, including supports, fixtures
  .18 Condenser, including special ducts to turbine exhaust valves
  .19 Supports, hangers, inserts, bases and screens
.2 Condensate cleaning system
.3 Condenser tubes cleaning system

234 Feedwater and main steam systems

.1 Main feedwater system
  .11 Piping (not included in 222.21)
  .12 Valves and fittings
  .13 Supports (piping related)
  .14 Insulation

.15 Feedwater, booster, startup and shutdown pumps, including motors, supports, fixtures
.16 Feedwater storage tank, including supports, fixtures
.17 Low pressure heaters, including supports, fixtures
.18 High pressure heaters, including supports, fixtures
.2 Emergency feedwater system
.3 Main steam system
.31 Main steam piping (not included in 222.21)
.32 Valves and fittings
.33 Supports (piping related)
.34 Insulation

235 Drain systems

.1 Plant drain system
.2 Building drain system

236 Other secondary side systems

.1 Conventional sampling system
.2 Steam generator blowdown system

These accounts should include all necessary components, equipment, piping systems, valves and fittings, supports, hangers, etc. The related I&C equipment and other electrical equipment should be listed under account 24.

24 Electrical equipment and I&C plant equipment

241 Generator and house load equipment

.1 Generator bus ducts, including erection materials
.2 Generator breaker system, including supports, hangers, fixtures and other related equipment
.3 Medium voltage switchgear
.4 Low voltage AC switchgear
.5 DC distribution and subdistribution equipment
.6 Batteries and chargers
.7 Converters and inverters, including control and monitoring equipment
.8 Earthing and lightning protection equipment
.9 Generator and station services protection, operation (synchronizing and change over) and monitoring equipment

242 Diesel and diesel control equipment

.1 Diesel motor and diesel generator, including accessories, control and monitoring equipment

243 Auxiliary electrical equipment

.1 Transformers
.11 Generator transformers
.12 Station service transformers
.13 Station startup transformers
.14 Low voltage and lighting transformers
.2 Motors
.21 High voltage motors (not included in driven component)
.22 Low voltage motors (not included in driven component)
.3 Cables and penetrations
.31 High voltage cables (1 kV and above)
.32 Low voltage cables (below 1 kV)
.33 High voltage special cables (above 1 kV, fire and radiation resistant)
.34 Low voltage special cables (below 1 kV, fire and radiation resistant)
.35 Buswork marshalling equipment
.36 Subdistribution and junction boxes
.37 Materials for cabling, sealing and installation
.38 Containment penetrations (not included in 212.7)
.4 Electrical supporting structures
.41 Cable trays and supports
.42 Cable conduits and supports

244 Ancillary and communication systems

.1 Lighting and installation systems
.2 Communication systems
.3 Fire alarm systems
.4 Clock systems
.5 Closed-circuit television

245 I&C equipment (conventional and nuclear)

.1 Process I&C equipment
(The respective mechanical system accounts should be referenced)
.11 Sensors and transmitters

.12 Signal processing equipment
.13 Open loop control system, including protective interlocking and disturbance annunciators
.14 Pumps and aggregate protection
.15 Control valve actuators and drives
.16 Closed loop control system
.17 Control boards in control rooms and local control boards (including instrument recorders, indicators, alarms and controls)

.2 Process computer
.21 Supervisory computer
.22 Other computers

.3 Turbine I&C equipment
.31 Sensors, transmitters on turbine
.32 Turbine control equipment
.33 Turbine monitoring equipment
.34 Testing equipment

.4 Nuclear instrumentation
.41 Primary coolant measuring equipment
.42 Sensors and transmitters for reactor protection system and auxiliary nuclear systems
.43 Loose parts monitoring system
.44 Seismic instrumentation
.45 Vibration monitoring system
.46 Ex-core instrumentation (electrical equipment)
.47 In-core instrumentation

.5 Nuclear control
.51 Reactor control
.52 Auxiliary nuclear equipment control

.6 Reactor protection system
.61 Equipment

.7 Radiation monitoring system inside plant
.71 Equipment
.72 Radiochemistry laboratory

.8 Instrumentation tubing

25 Water intake and heat rejection

251 Circulation water intake structures

.1 Circulation water intake canals
.2 Service water intake canals

.3 Circulation water intake works
.4 Service water intake works
.5 Circulation water cleaning structures
.6 Service water cleaning structures
.7 Circulation water supply culverts
.8 Service water supply culverts
.9 Other structures, such as:
- Biocide treatment building
- Screen wash water canals
- Screen wash cleaning structures and bridge, and special site related structures
- Ducting structures

252 Structures for circulation water pumping and outfall

.1 Circulation water pump structures
.2 Service water pump structures
.3 Process cooling water pump structures
.4 Circulation water overflow structures, surge tank
.5 Screen wash water discharge canals
.6 Circulation water seal pit, circulation water aeration structure 1
.7 Circulation water deaeration structures
.8 Service water surge pond
.9 Other structures, such as:
- Circulation water return culverts
- Service water return culverts
- Circulation water outfall structures
- Service water outfall structures
- Circulation water outfall culverts
- Service water outfall culverts
- Circulation water spillway structures
- Circulation water aeration structure 2
- Structures for artificial aeration of circulation water
- Routing structures for circulation water outfall
- Special structures (plant specific)
- Bridge structures
- Ducting structures

253 Structures for recirculation water cooling

.1 Cooling water structures (circulation water)
.2 Cooling water structures (service water)

.3 Cooling tower structures (process cooling water)
.4 Cooling tower pump structure (circulation water)
.5 Cooling tower pump structure (service water)
.6 Cooling tower pump structure (process cooling water)
.7 Cooling tower connection structures
.8 Cooling tower discharge structures
.9 Other structures, such as:
- Cooling tower recirculation structures
- Cooling tower recirculation culverts
- Cooling tower distribution structure
- Cooling tower bypass structures
- Cooling tower blowdown structures
- Cooling tower blowdown culverts
- Special structures (plant specific)
- Bridge structures
- Ducting structures

254 Main circulation water piping

255 Secured service water piping

256 Service water piping for conventional plant

257 Equipment

26 Miscellaneous plant equipment

261 Heating, ventilation and air-conditioning systems (HVAC)

.1 Ventilation and air-conditioning systems for reactor building, reactor auxiliary building, fuel building or other buildings in the controlled area(s)
.2 Ventilation and air-conditioning system, heating systems for all buildings not mentioned under 261.1

The following items should be accounted for in accounts 261.1 and 261.2, respectively:
- Air supply systems, consisting of:
  Filters, heaters, coolers, fans, blowers, humidifier systems, ducts, piping, armatures, valves and other special equipment (motors and actuators are included), supports, hangers, dampers, etc.
  I&C equipment as listed under account 24, if they are not integral parts of the HVAC equipment

- Off-air systems, consisting of:
  Filters, charcoal filters and others, blowers, fans, ducts, piping, armatures, valves, supports, hangers, dampers
  I&C equipment as listed under account 24, if they are not integral parts of the HVAC equipment

.3 Auxiliary boiler, complete unit

262 Fire protection and fire fighting systems

All fire protection and fire fighting systems for the complete nuclear plant should be listed under this account, for each specific building or area.

.1 Alarm system
.2 Sprinkler system
.3 Mobile installations
.4 Manually operated and hand-held fire fighting equipment
.5 Hose reels and cabinets
.6 Piping system, including valves, hangers, supports

263 Secondary side auxiliary systems

.1 Central gas supply system
.2 Hydrazine supply system
.3 Chilled water system for conventional plant and secured plant
.4 Central compressed air supply system
.5 Others

These accounts should include all necessary components, equipment, piping systems, valves, supports, hangers, inserts, insulation, etc. The related I&C equipment and other electrical equipment should be listed under account 24.

264 Water supply system

.1 Demineralizing system
.2 Demineralized water supply system

265 Cranes, hoists, elevators, gantry

Because of the differences in the various reactor systems, all cranes, elevators, hoists and gantries should be listed under this account and classified with respect to their location inside the plant.

.1 Polar crane inside reactor building
.2 Gantry crane outside reactor building
.3 Cranes in turbine building
.4 Cranes in reactor auxiliary building
.5 Elevators in reactor building
.6 Elevators in reactor auxiliary building
.7 Elevators in electrical building

266 Laboratory equipment

.1 Hot laboratory
.2 Conventional laboratory
.3 Radiological laboratory

All laboratory installations, i.e. furniture, measuring equipment and analytical equipment, should be listed under this account. Furthermore, the scope of supply for lighting, workshops and infrastructure inside the plant may be added in the same way as mentioned above.

27 Special materials

Initial supply of special (non-fuel and non-structural) moderator and/or reflector materials and special heat transfer fluids (other than natural water), gases or liquids (including reactor coolant, intermediate loop heat transport fluid and turbine cycle working fluids). Initial supply of oil, lubricants, ion exchange resins, boric acid, and N_2, O_2, He and CO_2 gases.

271 Reactor coolant (if not under fuel cycle, account 150)

272 Moderator (if not under fuel cycle, account 150)

273 Reflector material

274 Intermediate coolant

275 Turbine cycle working fluids

276 Initial materials

.1 Oil
.2 Lubricants

.3 Resins for ion exchanger
.4 Boric acid
.5 Gases: N_2, O_2, He, CO_2, Ar
.6 Others

28 Simulators

281 Simulator equipment (if not included in owner's costs, account 70)

.1 Instruction unit
.2 Simulation computer (main computer)
.3 Software package

30 Engineering, design and layout services provided by the supplier(s) and/or A/E at the home office(s)

All engineering activities performed at the home office(s) for layout, design, calculation, elaboration of technical reports as well as the preliminary safety analysis report and the final safety analysis report, specifications, licensing and quality assurance documents, etc.

301 Civil engineering, general plant layout and design

302 Mechanical engineering for systems, components and piping

.1 Reactor plant (NSSS, NI, BONI)
.2 TG plant (TG, conventional island, BOCI)

303 Electrical engineering for systems and components

.1 Reactor plant (NSSS, NI, BONI)
.2 TG plant (TG, conventional island, BOCI)

304 I&C, reactor protection engineering

305 Reactor physics, thermodynamics, thermohydraulics, plant dynamics, analogue computer analysis, earthquake analysis, chemistry and other engineering activities not directly component or system related

306 Construction and/or erection manuals and instruction preparation, commissioning instructions, operation procedures

307 Quality assurance measures and documentation at home office

308 Elaboration of licensing documents (preliminary safety analysis report, final safety analysis report, topical reports, etc.)

*31 Project management services provided by the supplier(s) and/or A/E at the home offic*e(s)

All project management services undertaken in the respective home office(s) should be listed under this account.

311 Project co-ordination inside the respective organization

312 Project co-ordination between supplier(s) or A/E and owner

313 Project co-ordination between supplier(s) or A/E and licensing authorities

314 Project co-ordination between supplier(s) and A/E at the home offices

315 Project co-ordination between supplier(s) and A/E at the plant site

316 Project co-ordination between supplier or A/E and other parties involved in the project

317 Time scheduling

318 Cost control

319 Other management services, such as interface management, co-ordination of construction services, commissioning activities, quality assurance and final documentation, training programme activities

32 Engineering, design and layout services provided by the supplier(s) and/or A/E at the plant site

Engineering activities at the site for design or redesign, updating, introduction of change orders or licensing requirements, re-planning of systems, etc., should be calculated or estimated under this account.

321 Civil engineering

322 Mechanical engineering for systems, components and piping

.1 Reactor plant (NSSS, NI, BONI)
.2 TG plant (TG, conventional island, BOCI)

323 Electrical engineering for systems and components

.1 Reactor plant (NSSS, NI, BONI)
.2 TG plant (TG, conventional island, BOCI)

324 I&C, reactor protection engineering

.1 Others

33 Project management service(s) provided by the supplier(s) and/or A/E at the plant site

Services at the site performed by the site management group of the supplier(s) and/or A/E for site co-ordination, supervision and management should be listed under this account.

331 Civil works

332 Mechanical systems, components and piping

.1 Reactor plant (refer to account 22) (NSSS, NI, BONI)
.2 TG plant (refer to account 23) (TG, conventional island, BOCI)

333 Electrical systems and components (refer to account 24)

.1 Reactor plant (NSSS, NI, BONI)
.2 TG plant (TG, conventional island, BOCI)

334 I&C, reactor protection, etc.

335 Administration, cost control, contracting, scheduling

336 Quality assurance

34 Construction site supervision by the supplier(s) and/or A/E

Construction supervisory services for the scope of supply of the supplier(s) and/or A/E should be calculated separately from the construction labour (account 35) if these activities are performed under separate contract with the owner.

341 Civil works

342 Mechanical systems, components and piping

- .1 Reactor plant (NSSS, NI, BONI)
- .2 TG plant (TG, conventional island, BOCI)

343 Electrical systems and components

- .1 Reactor plant (NSSS, NI, BONI)
- .2 TG plant (TG, conventional island, BOCI)

344 I&C, reactor protection, etc.

345 Others

35 Construction labour provided by the supplier(s) and/or A/E or construction companies at the plant site

All plant construction labour executed at the site should be listed under this account. Site fabrication of components has to be calculated under account 22 for the respective component.

351 Civil works

- .1 Civil structures (reactor, turbine, reactor auxiliary and switchgear buildings, etc.)
- .2 Mechanical structures (buildings as under account 351.1)

352 Mechanical systems, components and piping

- .1 Reactor plant (refer to account 22) (NSSS, NI, BONI)
- .2 TG plant (refer to account 23) (TG, conventional island, BOCI)

353 Electrical systems and components (refer to account 24)

.1 Reactor plant (NSSS, NI, BONI)
.2 TG plant (TG, conventional island, BOCI)

354 I&C, reactor protection (refer to account 24)

355 Others (refer to accounts 25 and 26)

36 Commissioning services provided by the supplier(s) and/or A/E at the plant site

All commissioning services, including startup, performed after completion of the erection work and up to the commercial operation of the plant should be listed under this account. Deviations from this definition have to be clearly stated.

361 Reactor plant equipment

.1 Reactor equipment as under account 221
.2 Main heat transfer and transport system as under account 222
.3 Reactor auxiliary systems as under account 223
.4 Reactor ancillary systems as under account 224
.5 Nuclear fuel handling and storage system as under account 225

362 TG plant equipment

.1 Turbine plant as under account 231
.2 Generator plant as under account 232
.3 Condensate systems as under account 233
.4 Feedwater and main steam systems as under account 234
.5 Drain systems as under account 235
.6 Other secondary side systems as under account 236

363 Electrical equipment and I&C plant equipment

.1 Generator and houseload equipment as under account 241
.2 Diesel and diesel control equipment as under account 242
.3 Auxiliary electrical equipment as under account 243
.4 Ancillary and communication systems as under account 244
.5 I&C equipment as under account 245

364 Water intake and heat rejection systems as under account 25

.1 Circulation water intake structures
.2 Structures for circulation water pumping and outfall
.3 Structures for recirculation water cooling
.4 Main circulation water piping
.5 Secured service water piping
.6 Service water piping for conventional plant

365 Miscellaneous plant equipment

.1 Heating, ventilation and air-conditioning systems as under account 261
.2 Fire protection and fire fighting systems as under account 262
.3 Secondary side auxiliary systems as under account 263
.4 Water supply systems as under account 264
.5 Cranes, hoists, elevators and gantry as under account 265
.6 Laboratory equipment as under account 266, as applicable

37 Trial test run services provided by the supplier(s) and/or A/E

All services necessary to perform the trial test run of the parts of the plant included in the scope of supply (NSSS, NI, BOP, TG, conventional island, etc.), delivered, erected and commissioned within the framework of the test run for the complete plant should be calculated under this account in order to obtain the guarantee values within the period of time agreed upon in the BIS.

371 NSSS or NI

372 BONI

373 TG island

374 BOCI

38 Construction facilities, tools and materials at the plant site

All costs of items, materials, structures and tools used for plant construction, and tools removed or dismantled after plant completion, should be listed under this account. Items, materials or structures which are permanent parts of the plant have to be included in accounts 21–27.

381 Site access and infrastructure improvements (specified in detail)

382 Buildings and structures (details should be specified under account 21)

.1 Field offices with installations
.2 Social buildings: canteen, hospital or medical service, shops, changing rooms, laboratories, rest rooms, apartment houses
.3 Warehouses, storage sheds, garages
.4 Workshops
.5 Guard houses, fences
.6 Fire fighting installations or measures taken during construction

383 Provisional installations during construction

.1 Water supply
.2 Gas supply (N_2, O_2, Ar, CO_2, etc.)
.3 Electrical supply for welding machines, temporary erection tools, lighting, ventilation
.4 Steam supply (steam boiler) with distribution system
.5 Compressed air station with distribution system
.6 Fuel for engines, turbines, boilers
.7 Waste storage and treatment
.8 Communication equipment (telephone, telex, telefax, TV and others)

384 Transportation installations not included in accounts 21–27

.1 Harbour crane
.2 Gantry
.3 Unloading equipment
.4 Lorries
.5 Scaffolds, ladders, stairways

385 Heavy construction equipment (e.g. conveyers, construction cranes, earth moving machinery, concrete batch plants, hoists, trucks)

386 Miscellaneous installations, materials, tools

39 Commissioning materials, consumables, tools and equipment at the plant site

391 Materials used during the commissioning period (filters, ion exchanger, chemicals, oil, lubricants, D_2O, Na, He, CO_2) and needed before commercial operation

392 Special tools (measuring equipment, reactimeter, etc.)

393 Others

40 Staff training, technology transfer and other services

401 Staff training

The scope of supply offered for training of O&M personnel should be listed under this account and the person-months evaluated; the qualification of the trainees and the respective levels of the training courses or programmes should be taken into account.

.1 Reactor plant operation personnel
.2 Reactor plant maintenance personnel
.3 I&C personnel
.4 Electrical and computer personnel
.5 Physicists, chemists, radiologists, etc.
.6 Operation personnel for conventional plant
.7 Maintenance personnel for conventional plant
.8 Other plant personnel
.9 Undergraduate and post-graduate education or other services

402 Technology transfer

.1 Transfer of written documents for:
  .11 Civil engineering
  .12 Mechanical, electrical and I&C engineering
  .13 Plant layout
  .14 Systems engineering for nuclear, conventional and electrical systems and components
  .15 I&C, reactor protection
  .16 Manufacturing
  .17 Construction, erection
  .18 Commissioning
  .19 Maintenance, in-service inspection and nuclear fuel cycle
.2 Transfer of computer programs and data pools
.3 Assignment and delegation of personnel
.4 R&D activities
.5 Formation of new companies and organizations in the owner's country
  .51 Engineering company

.52 Manufacturers of reactor plant equipment and conventional equipment
.53 Manufacturers of fuel assemblies
.54 Erection companies
.55 Enrichment facilities
.56 Intermediate storage for burnup fuel
.57 Licensing body
.58 Quality assurance organization
.59 Others

.6 Owner's scope

Technology transfer activities dealing with the owner's scope should be included in this account.

403 Simulator training (if not included in owner's costs, account 70)

.1 Preparation of instruction manuals
.2 Preparation of tests
.3 Preparation of input data
.4 Training
.5 Re-training

404 Other services

Services not included in the above accounts.

41 Housing facilities and related infrastructure

If it is necessary to have living quarters at the permanent site, all buildings and structures, including harbour, airport, TV station, radio station, hospital, fire fighting facilities, schools, sport facilities, shopping centres, etc., should be calculated under this account, in accordance with the requirements of the BIS.

Supplementary costs

50 Transportation and transportation insurance

51 Spare parts

52 Contingencies

53 Insurance

54 Decommissioning costs (if not included in O&M costs, account 870)

Financial costs (including accounts 21–54)

60 Escalation costs

61 Interest during construction

62 Fees

Owner's costs (excluding accounts 21–62)

70 Owner's capital investment and services costs

71 Escalation of owner's costs

72 Financing of owner's costs

Nuclear fuel cycle costs

100 Fuel assembly supply, *first core*

101 Uranium supply

102 Conversion

103 Enrichment

104 Fuel assembly fabrication

105 Supply of other fissionable materials

110 Services, *first core*

111 Fuel management (U, Pu, Th)

112 Fuel management schedule

113 Licensing assistance

114 Preparation of computer programs

115 Quality assurance

116 Fuel assembly inspection

117 Fuel assembly intermediate storage

118 Information for the use of third party fuel

120 Fuel assembly supply, *reloads*

121 Uranium supply

122 Conversion

123 Enrichment

124 Fuel assembly fabrication

125 Supply of other fissionable materials

130 Services, *reloads*

131 Fuel management

132 Fuel management schedule

133 Licensing assistance

134 Preparation of computer programs

135 Quality assurance

136 Fuel assembly inspection

137 Fuel assembly intermediate storage

138 Information for the use of third party fuel

140 Reprocessing of irradiated fuel assemblies

141 Credits for uranium, plutonium and other materials

142 Final disposal of fuel assemblies (in the case of no reprocessing)

143 Final waste disposal

150 Heavy water supply, *first charge* (if not included in capital investment costs)

151 Heavy water services, *first charge* (if not included in capital investment costs)

160 Heavy water supply, *replacement quantities* (if not included in O&M costs)

161 Heavy water services, *replacement quantities* (if not included in O&M costs)

170 Financial costs of the nuclear fuel cycle

171 Financial costs of heavy water (if not included in capital or O&M costs)

O&M costs

800 Wages and salaries for engineering and technical support staff and for operation, maintenance and administration staff

810 Consumable operating materials and equipment

820 Repair costs, including interim replacements

830 Charges on working capital

840 Purchased services

850 Insurance and taxes

860 Fees, inspections and review expenses

870 Decommissioning allowances (if not included in capital investment costs, account 54)

880 Radioactive waste management costs

890 Miscellaneous costs

Annex II

IAEA COMPUTER PROGRAM
FOR ECONOMIC BID EVALUATION

INTRODUCTION

The IAEA computer program package for economic bid evaluation, Bideval-3, is a set of computer programs designed to assist the user in the economic evaluation of bids for NPPs. The program follows the recommended method of determining the present value of all costs for capital investment, nuclear fuel, and operation and maintenance in order to obtain the LDEGC as described in this report. The program operates in a user-friendly, interactive mode.

This program is the second upgrade of the original version developed in 1986 for use on personal computers (PCs) and its source code was written in FORTRAN. The upgrade is also designed for use on PCs under Windows 95/Windows 98.

Annex II only describes the basic features of the methodology and the basic features of the control of the program.

II–1. MINIMUM REQUIREMENTS ON PC CONFIGURATION

- Processor (80386 DX or its equivalent);
- RAM (16 MB);
- Video subsystem (resolution 800 × 600, 256 colours);
- Hard disk capacity (20 MB for saving the program files of the application and for saving project data (depending on the extent of the project, an order of magnitude estimate up to 10 MB for each variant);
- Operating system (Windows 95/Windows NT English version, 32 bits (it is expected that it will also run without problems on Windows 98)).

Implementation on a user’s PC requires, in addition to the minimum hardware configuration described above, a software set-up for the non-clashing operation of the application. The specified volume of the application is comparable to the requirements on any common application and it should be commonly available on most of the PCs likely to be used for Bideval-3 sessions.

Greater user comfort, given mainly by shorter response time of particular actions, requires that more powerful PCs be used.

II–2. PROGRAM DESCRIPTION

II–2.1. Source program codes

The Bideval-3 software package contains several hundred smaller programs, unlike the previous versions (Bideval-1 and Bideval-2) where only a small number of very extensive source codes were used. Source codes, together with installation programs, are distributed by the IAEA on CD-ROM. Details of the procedure for installing the program on the user's PC are described below.

II–2.2. Executable program codes

The set of program codes executable on the user's PC is contained on the CD-ROM. The executable program codes are allocated from the installation set to the user's hard disk by the set-up utility (default allocation is C:\Programfiles \Bideval).

II–2.3. Program structure

The application (Bideval-3 program package) has been developed in the programming language Visual Basic 5 and data used by it are organized and stored in a relational database in MS Access, an integral part of the software package MS Office. The application works in the environment of the Windows operating system and utilizes its graphics as well as other system possibilities.

Such a combination enables the application to run in a similar way to any application of the MS Office or to other commercial MS applications. A user works in working control forms ('windows'). For control of the entire application, a combination of menu system and functional buttons is used, as well as tools to assist a user, such as 'Help', 'Clipboard', 'Tool tips', etc. The majority of situations can benefit from the use of 'wizards' designed to help users (beginners), which in certain sections of the package make entering the data more effective for all users.

The application has been designed for a user who is familiar with the basics of running Windows and its applications, and for such a user the control of the program should pose no problem. The working platform of the application is Windows 95 or Windows NT.

Many data may be selected from the prepared values and the editing of many data is secured as far as the integrity of project data is concerned. Wizards are used to make data entry easier for users.

The program package includes two dedicated utilities: the first for modification of the IAEA costs account structure (EditAc) and the second for facilitating performance of sensitivity analysis on the results of the calculations.

Section II–8 contains the following flow charts:

- Bideval-3 main flow chart,
- Capital costs segment flow chart,
- Fuel cycle costs segment flow chart,
- O&M costs segment flow chart,
- Sensitivity analysis flow chart.

II–2.4. Project

Details of the project, together with all its data components, are stored in a database structured MS Access file. To achieve unambiguous identification of the application, the file extension 'eva' has been selected. Storing the data for a single project in only one file is important in securing the data and its integrity, as well its manipulation.

II–2.5. Databases

The application works with data stored in relational databases, thus enabling processing of the large amount of data the program package uses.

II–3. SETTING UP BIDEVAL-3

A standard procedure used for a current, commercial software application is used. The set-up process is started by the program 'Setup.exe' from the IAEA distributed disk (either floppy disk or CD-ROM), which is then followed by the usual interactive communication with the user regarding allocation of the program components.

II–4. RUNNING THE APPLICATION

The following paragraphs only give a very brief description of the control of the software package. Bideval-3 has been developed as a Windows application. Therefore, the usual start of a program is from the 'Start Menu' for Windows 95/ Windows NT or by other procedures which a user is accustomed to.

The user can then select which cost component is to be considered at that time: capital investment, O&M or nuclear fuel. Any combination of components may be selected for a run.

The application has been debugged for Windows 95 (English version) where the decimal point is displayed as '.' and the digit grouping symbol as ' '. For different regional settings these symbols may be displayed in a different way.

II–4.1. TCIC

Several different types of data must be entered to produce a value for the TCIC. Data related to base or fore costs, currencies, supplier payments, cost escalation and financing must be considered. The entire program package provides menu selection of the data which the user wishes to enter at any given time; not all data need be entered during the same run.

The base cost data are entered by IAEA account number as defined in Annex I. In addition to the base costs, separate cost adjustments, also expressed as fore costs, may be entered. These economic adjustments are for those fore costs which are not directly included in the bid, but which are required for equalizing the scope of supply and services and for bringing the offered bids to a comparable state. Economic adjustments may be entered at any place where base costs are entered, also it is not necessary that a base cost be present for the user to enter a cost adjustment.

Also related to the base costs is the setting of certain ‘flags’ or reference names for other data to be entered. The user supplied flag names are used by the program to associate the base cost data with the appropriate price escalation schedule, supplier payment schedule and financing package. In the capital cost portion, three flags must be set at least once for each two digit account level containing costs. These flags observe the hierarchical nature of the cost account structure which allows the flags to be set, for instance, at a two or three digit level and yet apply to the detailed base costs entered at the four or five digit level. The three flags are always set together and once set include all costs lower in the hierarchy. The selection of names for all flag types is left to the user. However, it is recommended that the user chooses flag labels similar to those shown in the example cases.

TABLE II–1. SUPPLIER PAYMENT SCHEDULES BY IAEA ACCOUNT (%)

	Two digit account number					
Year	21, 38, 41	22–26, 35, 50	30, 32	31, 33, 34, 52, 53	36, 37, 39, 40, 51	70
1999	25	15	40	12.5		10
2000	40	10	40	12.5		10
2001	25	15	10	12.5		10
2002	10	20	10	12.5		10
2003		15		12.5		10
2004		10		12.5	10	10
2005		10		12.5	50	15
2006		5		12.5	40	25

The number of currencies that may be utilized by the program is limited only by the storage capacity of the PC (hereinafter unlimited). One of these currencies must be identified as the reference currency. Each currency is identified by its code. When new currency data are entered, a currency code is requested and a currency description may be added as an option.

Cost escalation patterns are entered by reference to the flag ‘name’. The program allows the use of weighting factors and index values, which are combined to form a composite escalation index. The data may be entered for each month as annual percentage rates. For data input, the costs occurring in the intervals between input points escalate at the current escalation rate.

Supplier payment data are identified by a string (character) variable. As for the escalation data, all supplier payments must be made within 200 years of the base cost date and may be entered as percentages of the total reference costs at any date prompted from a scroll bar. Table II–1 lists the supplier payments used in the example cases.

The financing package data are entered under the user-assigned financing package flag name. Each financing package can consist of an unlimited number of separate funding sources. Separate financing packages must be defined both for base costs and for escalation costs. The contribution from each funding source may change during the construction period. This feature has been used in the example case.

For each funding source, the interest rates may vary with time. An estimate of the loan limit must be entered, since the fees are calculated as a percentage of this loan limit. If this limit is not known, the program may be run with a fictitious value and may be corrected later by inserting the calculated value of the loan limit at the end of the column cumulative outstanding debt.

When all data are entered, the calculation of the TCIC may be started from the Calculation Wizard in the Wizards menu. Once the calculation is completed, it is possible to print output reports. The available reports list (including input data reports) may be selected from either the Calculation Wizard or the Reports Wizard. The construction cost summary for all costs incurred during the construction period may be also printed. It should be noted that the interest and fees presented in the construction cost summary are only those incurred during the actual construction period and exclude the financing costs incurred after the start of commercial operation.

II–4.2. O&M costs

As in the case of the capital investment costs portion of the program package, the input options for the O&M costs are selected from either the Project menu or the Wizards menu. The base cost data are entered following the IAEA account structure presented in Annex I. For the O&M portion of the program, all costs are entered in the reference currency only. Both the fixed costs and the costs that vary with respect to energy generation can be used for all accounts. Cost data over time are entered on an annual basis; they may be entered for any year up to 200 years from the base cost date. The behaviour of the cost data over time may be expressed either in terms of an escalation rate or in absolute amounts.

Annual energy generation data for three products: electricity (GWh/y), heat (TJ/y) and another product must be input at this stage if variable O&M costs exist. The energy production data can be provided by specifying either the direct input in physical units or the net power output and the annual capacity factor. When all data have been supplied, the calculation option may be selected.

II–4.3. Nuclear fuel cycle costs

The fuel cycle portion of the computer package considers costs related directly to the nuclear fuel cycle, such as those for fabrication and enrichment, as well as costs related to the use of heavy water, as applicable. The base cost data are entered with reference to the IAEA accounts for each fuel cycle. A fuel cycle is defined as the period encompassing a single loading and/or unloading of fuel or a single charge of heavy water. An upper limit to the number of fuel cycles and/or heavy water charges is given by the previously stated time limit of 200 years.

Each fuel cycle (or heavy water charge) must have a reference date associated with it because supplier payment dates are entered in time units relative to the cycle (charge) reference date. Since the program summarizes the initial core load/heavy water charge separately from the reloads/recharges, the first data set for the fuel cycle has to represent the initial core and the first data set for heavy water has to represent the initial heavy water inventory, as applicable.

It is important to distinguish between a fuel cycle data set as used in this code and a fuel batch data set as used in other fuel cycle cost codes. The materials entered in a given fuel cycle data set in this program are those materials which cross the reactor vessel boundary at a given refueling. In other words, included in a fuel cycle data set are the new materials coming into the reactor and the old materials leaving the reactor. In terms of fuel batches, a new batch of fuel and an old batch of fuel are linked to a common fuel cycle data set by their common refueling date.

The base cost data are entered in each nuclear fuel cycle account as a unit cost and as a quantity. In addition, a cost adjustment value may be applied. The costs may be in any currency used and flags must be set to identify the data for supplier payments and financing. There is no escalation flag in this portion because escalation is reflected either directly in the unit cost data for each cycle or by using the escalation rate in the Fuel Costs Wizard when generating new fuel cycles.

The reference base costs and data for the nuclear fuel cycle used in the example case are given in Table II–2. The unit costs in the table are expressed for consistency in US dollars (as of 1 Jan. 1999), but the values actually entered in the computer data file are in the currencies for which exchange rates are given in the table. An 18 month refueling cycle has been assumed. It should be noted that credits, if applicable, are entered as negative values and plutonium credits are shown separately in the cost adjustment column (economic adjustments).

The treatment of financing of fuel cycle costs is similar to that of capital investment costs. A financing package is identified for each non-zero cost component. The proportion of the costs supported by each funding source may change over time. Up to 500 separate loans may be included.

II–4.4. Total plant costs and LDEGC

A summary of the total plant costs with total present value and the LDEGC for the three cost components is in the 'Total costs summary' report and, as with other reports, is accessible, e.g. from the Reports Wizard. However, the complete cost summary can only be obtained after all three cost components and the energy generation data have been considered by the program.

II–4.5. Modification of account systems

It is conceivable that a user may wish to use a different account system from that given in the technical report. It is not difficult to modify the account numbers or titles used in the computer program.

EditAc is a supplementary application (utility) for Bideval-3 that is automatically installed during set-up of the entire Bideval-3 package. It permits editing the built-in IAEA account system, i.e. entering new accounts, deleting accounts and modifying descriptions of existing accounts.

The utility is started from a folder of 'exe' modules ('EditAc.exe') allocated in the folder selected during installation of the Bideval-3 package (default allocation C:\Programfiles\Bideval\).

The utility is controlled by a user from a single form displaying the IAEA account system. Editing itself is performed from a tool bar and particular buttons contain 'Tool tips' for easier orientation of the user.

Selection of a project file where the accounts are to be edited is done by selecting the File menu, which is typical for Windows. Should the user require that changes made be valid for all new projects, a file ('Empty.eve') must be edited in the same folder to which the 'Bideval.exe' file has been allocated, usually in C:\Programfiles\Bideval\.

TABLE II–2. ESTIMATED BASE COSTS AND DATA FOR THE NUCLEAR FUEL CYCLE

COST DATA:

	Unit costs (1999 US $)	Escalation (%, real)	Losses (%)
Uranium ore	52/kg U (44/kg U_3O_8)	0.0	
Conversion	8/kg U	0.0	0.5
Enrichment (SWU)	100/kg	0.0	
Fabrication	400/kg U	-0.5	1.0
Back end fuel cycle	1 million/kW·h		

MATERIALS QUANTITIES:

	First core	Reload	Originating country
Uranium ore	444 500 kg U (524 222 kg U_3O_8)	154 289 kg U (181 961 kg U_3O_8)	Canada
Conversion	442 774 kg U	153 690 kg U	United Kingdom
Enrichment (SWU)	223 217 kg U	90 019 kg U	France
Fabrication	49 533 kg U	17 199 kg U	Germany

ECONOMIC PARAMETERS:

	Exchange rate (Units/Euro)	General inflation (%/year)	Currency code
Canadian dollar	1.54	2.0	CAD
US dollar	1.10	2.0	USD
British pound	0.67	2.0	GBP
Euro	1.00	1.5	EURO

PAYMENT SCHEDULES:

	Time relative to refueling (years)	Percentage of total (%)
Uranium ore	–2.0	50
	−1.5	50
Conversion	−1.5	50
	−1.25	50
Enrichment	−1.0	100
Fabrication	–0.5	100
Waste disposal	+8.0	50
	+9.0	50

II–5. EVALUATION METHOD

II–5.1. General

As discussed in Section 5 of the technical report, the recommended method for performing an economic bid evaluation is to obtain the LDEGC over the selected operating period. The IAEA computer program package for economic bid evaluation determines the LDEGC by analysing the three major cost components, namely, the TCIC, the nuclear fuel cycle costs and the O&M costs. The order in which the user analyses these three cost components is irrelevant. The main program flow gives the user the opportunity to access any cost components during a given run, as desired (see Section II–8).

In general, the program calculates the LDEGC according to the following equation:

$$\text{LDEGC} = \frac{\text{PW(CAP)} + \text{PW(O\&M)} + \text{PW(FUEL)}}{\text{PW(ENERGY)}} \tag{II–1}$$

where PW stands for the present worth of the quantity inside the brackets.

For each of the three present worth costs, the procedure is to discount all buyer's cash requirements, either from the direct payments or from the finance arrangements, at the appropriate nominal discount rate at a point in time for which the exchange rate is known, and then to convert these currencies to a common reference currency. The equation for the calculation of the present worth of each currency (e.g. B) expense is as follows:

$$\text{PW} = E_{A/B} \sum_{t=T_R}^{T_E} \frac{C_{B_t}}{\left(1+e_{iB}\right)^{t-T_r}\left(1+d_r\right)^{t-T_r}} \tag{II–2}$$

where C_{Bt} is the cash requirement in currency B at time t, e_{iB} is the general inflation rate for currency B, d_r is the real discount rate, T_E is the end of the period under study or the end of decommissioning, T_R is the reference date, and $E_{A/B}$ is the exchange rate to the reference currency A which is assumed to be known at time $t = T_R$ (see Section 5, Eqs (14 and 15), and Appendix I, Eqs (28–32)).

For the calculation of the present worth of the energy generation to be used in determining the LDEGC, a step is required which should be discussed. In the analysis it is assumed that the revenues for the sale of electricity are received by the buyer in a reasonably continuous flow. This means that more than a single payment is received during the course of an operating year. Therefore, the program performs a continuous discounting of the energy generation during a given year to obtain the present value of the energy for the start of that year. Normal discrete discounting is then used to obtain the present value of the energy for the reference date. There are two cases to be presented as follows:

1) First case: levelized generation cost to be expressed in constant money (reference currency at the reference date). The present worth of the energy PW(ENERGY) for a given year t at the beginning of the year is:

$$\mathrm{PW(ENERGY}_t) = \frac{\mathrm{ENERGY}\left\{1 - \exp\left[-\ln(1+d)\right]\right\}}{\ln\left(1+d_r\right)} \tag{II–3}$$

where d_r is the real discount rate.

The energy generated over the plant lifetime is then calculated in terms of present worth to the discounting date (as indicated by ‘B1’ in Table IX) as follows:

$$\mathrm{PW(ENERGY}_{t=T_D}) = \sum_{t=T_0}^{T_L} \frac{\mathrm{PW(ENERGY}_t)}{\left(1+d_r\right)^{t-T_D}} \tag{II–4}$$

where: T_D is the date to which discounting is performed
T_O is the date of commercial operation
T_L is the date of end of plant life
(in this software $T_D = T_B = T_R$).

2) Second case: levelized generation cost to be expressed in current money (reference currency of mixed years value). The present worth of the energy PW(ENERGY) for a given year t at the beginning of the year is:

$$\mathrm{PW(ENERGY}_t) = \frac{\mathrm{ENERGY}_t\left(1 - \exp\left\{-\ln\left[\left(1+e_i\right)\left(1+d_r\right)\right]\right\}\right)}{\ln\left[\left(1+e_i\right)\left(1+d_r\right)\right]} \tag{II–5}$$

where e_i is the general inflation rate for the reference currency ($e_i = e_{iA}$) and d_r is the real discount rate.

The energy generated over the plant lifetime is then calculated in terms of present worth to the discounting date (indicated by ‘B2’ in Table IX) as follows:

$$\mathrm{PW}(\mathrm{ENERGY}_{t=T_D}) = \sum_{t=T_O}^{T_L} \frac{\mathrm{PW}(\mathrm{ENERGY}_t)}{(1+e_i)^{t-T_D}(1+d_r)^{t-T_D}} \quad \text{(II–6)}$$

II–5.2. TCIC

The flow chart in Section II–8.2 gives an overview of the data entry portion of the computer program for the TCIC. As shown, the user can select the desired subject as required. Most of the data entry programs merely record the user's input data. However, two procedures should be mentioned separately. Firstly, the treatment of the TCIC escalation follows the method described in Section 5 of the technical report, i.e. a composite escalation coefficient is determined on the basis of up to seven weighted influence factors. For any given time *t*, the escalation coefficient is calculated as follows:

$$\mathrm{ESC}_t = \sum_{i=1}^{7} w_i \mathrm{ESC}_{i_t} \quad \text{(II–7)}$$

where w_i is the ith weighting factor and ESC_i is the ith applicable escalation factor at any given time *t*.

Secondly, although the program internally keeps time related data on a quarterly basis, supplier payments may be specified at any point in time. Payments made in the course of a quarter are prorated by the program in two parts to the beginning or the end of the quarter in which the payments were made. Thus, the two substitute payments for the actual payment PYMT_t can be expressed as follows:

$$\mathrm{PYMT}_q = (1 - f) \times \mathrm{PYMT}_t \quad \text{(II–8)}$$
$$\mathrm{PYMT}_{q+1} = \mathrm{f} \times \mathrm{PYMT}_t \quad \text{(II–9)}$$

where *f* is the fraction of a quarter beyond quarter *q*.

The calculation of the TCIC is performed according to the flow chart shown in Section II–8.2. For each currency used, the reference costs are grouped by their applicable flag (see previous section for information on flags) and added to the appropriate account level. Cash flows to suppliers are then determined and assigned to the appropriate loan drawing file(s) or owner cash requirements file. When all reference cost currencies have been considered, the evaluation of the loans is started. For each loan, the fees and interests are calculated on the basis of the drawing or borrowing schedule. Three types of fees are considered in the loan analysis: a management fee, a commitment fee and a fee for a guarantee letter of credit (GLCF).

The management fee is a one time fee to be paid at the beginning and is expressed by the formula:

$$\text{management fee} = \text{loan limit} \times \text{fee percentage} \qquad \text{(II–10)}$$

The commitment fee, charged for the period over which funds may be borrowed, is defined for the nth period as:

$$\text{commitment fee}_n = (\text{loan limit} - \text{amount borrowed}_{n\text{-}1}) \times \text{fee rate} \qquad \text{(II–11)}$$

The fee for the guarantee letter of credit, which provides an additional assurance of repayment to the lender, is expressed as:

$$\text{GLCF} = \text{loan limit} \times \text{fee rate} \qquad \text{(II–12)}$$

for the borrowing period, and as

$$\text{GLCF}_n = (\text{loan limit} - \text{amount repaid}_{n\text{-}1}) \times \text{fee rate} \qquad \text{(II–13)}$$

for the repayment period (period n).

The repayment schedule is calculated on the basis of either equal principal repayments, or equal repayment amounts. The user may also specify a different schedule. In the first case, the repayment amount for each period is simply the total debt outstanding at the start of repayment divided by the number of repayments. In the second case, the repayment amount is defined by the standard equation:

$$\text{repayment amont} = \frac{r(1+r)^N}{(1+r)^N - 1}\ (\text{total debt}) \qquad \text{(II–14)}$$

where r is the interest rate and N is the number of repayments.

For the repayment period, the interests and the GLCF continue to be calculated, as applicable. The owner's cash requirements are also calculated for this period.

When all loans have been considered, the program determines the present worth of the owner's cash requirements expressed in the reference currency, using the real discount rate as well as the appropriate inflation and exchange rates, as discussed in Section II–5.1.

II–5.3. O&M costs

The simplest of the three cost programs is the O&M costs program. As shown in Section II–8.4, O&M cost data are entered on an annual basis as fixed and/or variable costs in the reference currency. Variable costs are directly proportional to the annual energy generation. All O&M costs are assumed to be paid directly by the owner (there are no O&M finance packages) and represent cash requirements at the time when the costs are incurred.

In the present worth calculation of the O&M costs, it is assumed that the costs for a given year are not all incurred at a single point in the year but rather are distributed uniformly over the year. The present worth expression for a given year at the beginning of the year is as follows:

$$\mathrm{PW}(\mathrm{O\&M}_t) = \frac{(\mathrm{O\&M}_t)(1 - \exp\{-\ln[(1 + e_i)(1 + d_r)]\}}{\ln[(1 + e_i)(1 + d_r)]} \qquad \text{(II–15)}$$

where e_i is the general reference currency inflation rate and d_r is the real discount rate.

The present worth for the entire economic life of the plant is as follows:

$$\mathrm{PW}(\mathrm{O\&M}) = \sum_{t=T_0}^{T_L} \frac{\mathrm{PW}(\mathrm{O\&M}_t)}{(1+e_i)^{t-T_D}(1+d_r)^{t-T_D}} \qquad \text{(II–16)}$$

where: T_D is the date to which discounting is performed
T_O is the date of commercial operation
T_L is the date of the end of plant life.

II–5.4. Nuclear fuel cycle costs

The program for the nuclear fuel cycle costs operates in a similar manner as the program for the TCIC. The user has flexibility in the order in which data are entered. Both nuclear fuel cycle costs and heavy water costs may be considered in this program. Supplier payments are handled according to the method described earlier in Section II–5.2. When all data are entered, the calculations may be started. The flow of the calculations is very similar to the calculation procedure for the TCIC; the discussion of the financial computations in Section II–5.2 is also relevant to the nuclear fuel cycle costs.

When all loans have been considered, the program determines the present worth of the owner’s cash requirements expressed in the reference currency, using the real discount rate as well as the appropriate inflation and exchange rates, as discussed in Section II–5.1.

II–6. EXAMPLE CASE

An example has been provided for demonstration purposes and having the following parameters:

- Electrical output: 1144 MW(e).
- Base cost date: January 1999.
- Commercial operation date: January 2006.
- Economic life: 360 months.
- Reference currency: Euro.
- Real annual discount rate: 8%.

Input data, as well as results of calculations on the reports, are demonstrated on the following report set.

II–6.1. Main Bideval-3 reports

These reports are to be found in tabulated format in Annex II of the accompanying CD-ROM.

Capital costs

- Costs input data by account and currency,
- Supplier payment schedules by account and currency,
- Supplier escalation schedules by account and currency,
- Funding sources by financing flags and currency,
- Loans input data,
- Summary of capital costs input data by 2 digit account and currency,
- Application of loan proceeds by loan,
- Capital costs loan analysis by loan and currency,
- Cash requirements/present value in currency,
- Summary of capital costs cash requirements in reference currency,
- Summary of construction costs in reference currency.

O&M costs

- O&M input data by account and year,
- O&M costs summary by year in reference currency,
- Summary of O&M costs cash requirements in reference currency.

Fuel costs

- Fuel costs input data by account, currency and fuel cycle;
- Supplier payment schedules by account and currency;
- Funding sources by financing flags and currency;
- Loans input data by currency;
- Summary of fuel costs input data by account and cycle in reference currency;
- Fuel costs loan analysis by loan and currency;
- Summary of fuel costs cash requirements in reference currency;
- Cumulative nuclear fuel cycle costs in reference currency.

Other project reports

- Base project technical and economic parameters;
- Input data for currencies entered;
- Generation of electricity (heat and other products) by quantity and year;
- Report on calculation process, including error messages;
- Summary of total costs — discounted levelized generation costs in reference currency.

II–7. SENSITIVITY ANALYSIS

Sensitivity analysis used for assessment of risks resulting from chosen values of key economic parameters can be carried out quickly with the computing and graphics capabilities of Bideval-3. Sample sensitivity analyses were carried out on the following parameters, as recommended by IAEA experts:

- Discount rate
- Escalation rate
- Interest rate
- Load factor.

A special tool to assist users (labelled Sensitivity analysis) has been prepared and is accessible from the Wizards menu. The user is prompted to select which parameters are to be analysed. Some of the parameters may vary over time and therefore an analysis is performed to take account of the relative variation. In the course of computations, working versions of projects are generated, criteria functions are calculated and the results transferred to an MS Excel format file *.xls in folder

\Bideval\Data\Sensitivity. The file contains the results, the working versions of projects, and their graphics processing. The graphics' parameters may be modified according to user's wishes. Owing to the need to calculate several projects, a sensitivity analysis tends to be time consuming.

II–8. FLOW DIAGRAMS

Flow diagrams of Bideval-3 segments are shown as follows:

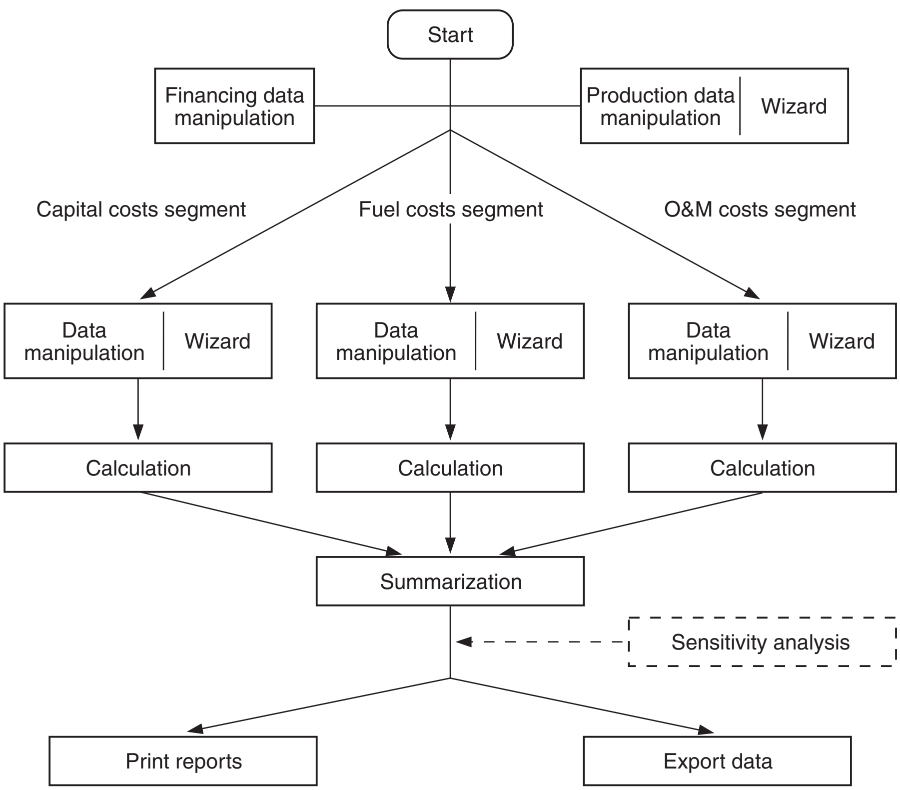

FIG. II–1. Bideval-3 main flow chart.

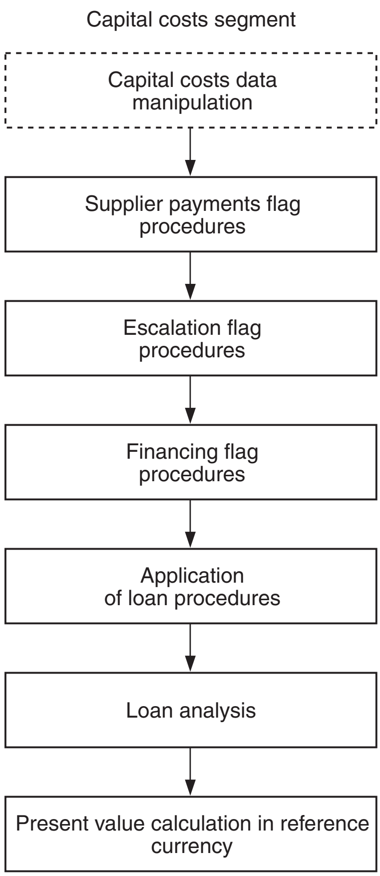

FIG. II–2. Capital costs segment flow chart.

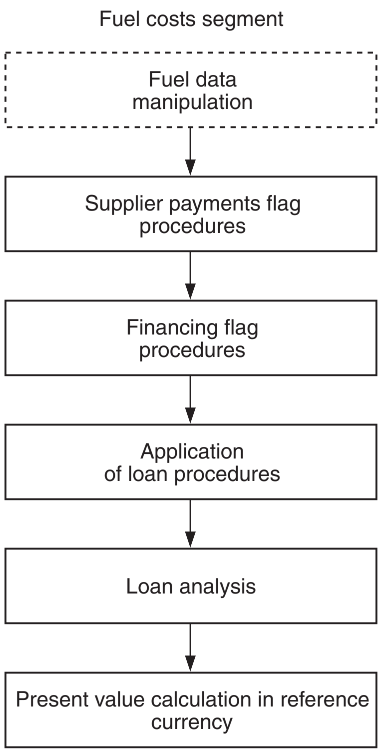

FIG. II–3. Fuel cycle costs segment flow chart.

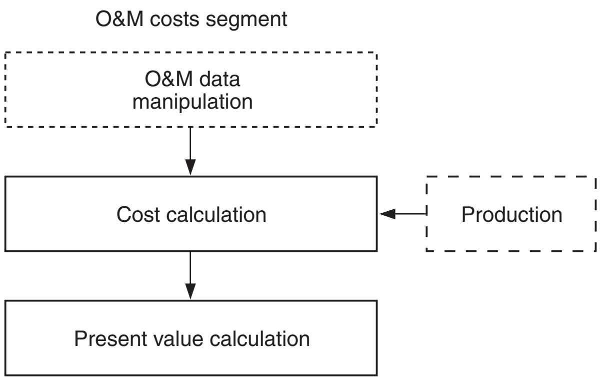

FIG. II–4. O&M costs segment flow chart.

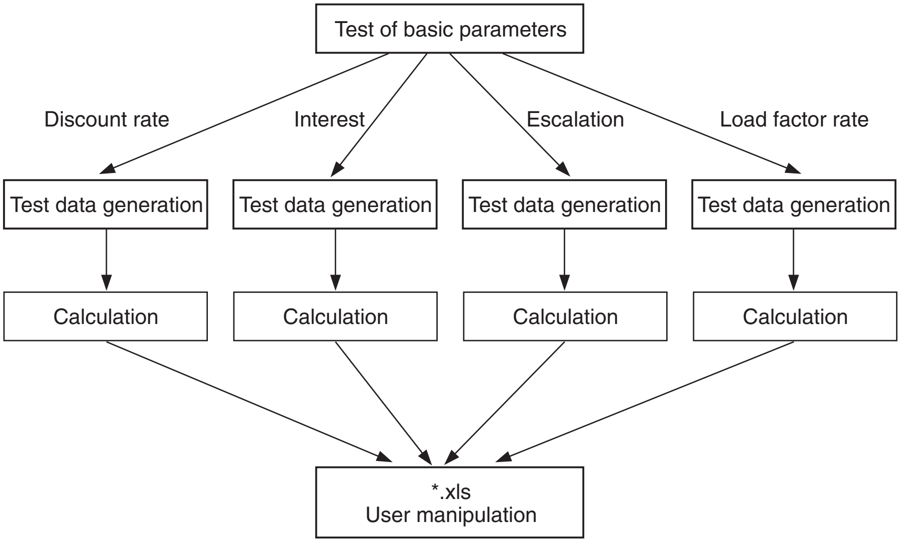

FIG. II–5. Sensitivity analysis flow chart.

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GLOSSARY

The definitions given below may not necessarily conform to definitions adopted elsewhere for international use.

allowance for funds used during construction (AFUDC). See **interest during construction (IDC)**.

availability factor. Over a specified period, the ratio of the energy that the available capacity could have produced during this period to the energy that the average maximum capacity would have produced during the same period.

back end of the nuclear fuel cycle. Activities involving the shipping of spent fuel, spent fuel storage, spent fuel reprocessing and waste management, and final disposal of reprocessing wastes and spent fuel.

balance of conventional island (BOCI). All components, equipment and systems included in the conventional island scope, with the exception of the turbine generator plant.

balance of nuclear island (BONI). All components, equipment and systems included in the **nuclear island** scope, with the exception of the **nuclear steam supply system (NSSS)**.

balance of payments. A systematic record of the economic transactions of the residents of a country with the rest of the world. It covers the flows of real resources (including factor services, such as the services of labour and capital) across the boundaries of the domestic economy, changes in foreign assets and liabilities resulting from economic transactions, and transfer payments to and from the rest of the world.

balance of plant (BOP). All items necessary to complete an **NPP**, with the exception of the **NSSS**.

base construction costs. The sum of the direct and indirect costs, and a part of the **total capital investment costs (TCIC)**. In some evaluations, the owner's costs are included in the base construction costs.

bid evaluation. An appraisal to determine whether or not an invited bid is capable of producing the desired product or service of a stated quality and what rank may be assigned to it relative to other invited bids offered at the same time.

bid invitation specification (BIS). A detailed description of equipment, components and services for an **NPP**, provided by the buyer to the prospective suppliers which are invited to bid. The information should be as complete as possible so that the suppliers obtain a clear understanding of what the buyer wishes to purchase, what its requirements are and what the conditions and circumstances are under which the suppliers' tasks are expected to be performed. Furthermore, the specification is intended to present to the bidders the buyer's request for information in a manner that will facilitate the buyer's bid evaluation. Finally, the specification is intended to serve as the basis for the contract documents, which are drawn up with the successful bidder.

bond. A certificate of indebtedness issued by a government or public company which promises to repay a specified sum of money at a certain date in the future or periodically over the course of a loan. **Interest** is paid at a fixed rate on specified dates.

capacity (of a power plant). The electric power for which a generating unit or station is rated (in MW(e)) under the specific conditions defined by the manufacturer.

capacity factor. See **load factor**.

cash flow. The movement of money, either into the project (termed revenues) or out of the project (termed disbursements).

commercial bank. A financial institution which provides a wide range of services, including accepting deposits and making loans for commercial purposes.

commercial operating date. The date when a unit/plant is declared to be available for the regular production of electricity (also referred to as start of commercial operation).

consortium. An association of independent companies formed to bid for a project and, if successful, to undertake the implementation of the project for which the skills and resources required are not possessed by a single company.

constant money. Monetary units of a constant purchasing value. The particular purchasing value chosen is that of the reference date.

constant money analysis. An analysis made without including the effect of **inflation**, although **real escalation** is included. The **discount rate** is the absence of **inflation** (i.e. the real discount rate) and must be used.

contingency. Specific provision for unforeseeable elements of cost within the defined project scope.

contract. An agreement between the buyer and the contractor(s), incorporating by reference the **BIS** and including modifications thereto as agreed from time to time by the parties to the agreement.

contractor. A bidder whose bid has been accepted by the buyer, with or without modifications, and which enters into a contract with the buyer.

contract price. The sum specified in the contract agreement to be paid by the buyer to the vendor.

cost–benefit analysis. A technique which attempts to set out and evaluate the social costs and benefits of investment projects in order to help decide whether or not the projects should be undertaken.

current money or mixed-years money. As related to investment cost, the arithmetical sum of monetary units spent in different years. The sum is mixed because it is a sum of money of different purchasing values. The monetary units are ‘current’ because they were spent according to their then current value.

current money analysis. An analysis that includes the effects of **inflation** and **real escalation**.

debt service. The sum of interest payments and repayments of principal on external debt. The debt service ratio is the total debt service divided by exports of goods and services.

decommissioning costs. A given amount periodically invested in a **sinking fund** or other instrument for the purpose of funding the decommissioning of an **NPP** to a ‘green field’ or other approved status at the end of its economic life.

depreciation. The reduction in value of an asset through wear and tear or any other factor that reduces its usefulness.

development agencies. Specialized public and private financial intermediaries providing medium and long term credit for development projects.

direct costs. Costs of all materials, equipment and labour involved in the fabrication, installation and erection of facilities.

discount rate. The rate of **interest** reflecting the time value of money that is used to convert benefits and costs occurring at different times to equivalent values at a common time. Theoretically, it reflects the opportunity cost of money to a particular investor (or, in broad terms, in a particular country).

equity financing. Investment conferring whole or partial ownership in an enterprise and entitling the investor to share the profits from its operation.

exchange rate. The price at which one currency is exchanged for another currency. The actual rate at a given time is determined by supply and demand in the foreign exchange market.

export credits. Finance provided by lenders in a country for export of specific goods or services. Conventionally, a distinction is made between private and official export credits. **Private export credits** consist of: (a) supplier credits, which are extended by the exporting company to the foreign buyer, and (b) buyer credits, which are extended by **commercial banks** in the exporting country on behalf of the exporters. **Official export credits** are extended by an agency of the exporting country's government.

fees. Amount of money payable for a certain service (usually commitment fees and management fees); this may be included in a loan agreement either as a lump sum payment during the first loan instalment disbursement or as an added margin on the loan repayments.

financial costs. The cost of providing funds to pay for construction of a major project, and a part of the **TCIC**.

firm price. A price or quotation in the bid that is binding on the bidder if it is accepted during the validity period of the bid and which is subject to the conditions specified in the **BIS**. A firm price may be increased only as a result of increases in labour and materials costs, in accordance with formulas agreed upon before the award of the contract.

fixed costs. Costs which are independent of short term variations in the output of the system under consideration. Fixed costs include the costs of labour, maintenance, technical service and laboratory expenses, taxes and insurance, and plant overheads and administration.

fixed interest rate. The rate of **interest** agreed upon which remains constant over the duration of the loan (loans from export credit agencies normally have fixed **interest rates**).

fixed price. A price or quotation in the bid that is binding on the bidder if it is accepted during the validity period of the bid. It is based on delivery consistent with the commercial operation date and implies that there will be no price increase because of escalation or for any other reason.

floating interest rate. An interest rate that varies during the life of a loan, according to an agreed formula. Usually it is based on benchmark interest rates, such as the LIBOR, the US prime rate or the Eurodollar bond rate.

force majeure. A clause in a contract providing for a party to the contract to be excused from fulfiling the terms of the contract in the event of war, strikes and other such events beyond the party's control.

fore costs. The **overnight** construction costs of a power generation facility, including all direct and indirect costs, owner's capital investment and services costs, and commissioning expenses, spare parts and contingencies. These costs exclude escalation and **interest** charges.

free on board (fob). A price quotation indicating that the supplier is responsible for all costs incurred during the shipment of goods, including the costs of damage or loss, to a certain location. For example 'fob buyer's plant' means that the supplier is responsible for the costs of the goods, and for their transportation and delivery in good condition at the owner's plant. The owner takes title to the goods only when they are delivered to the loading dock of the plant.

free alongside ship (fas). Similar to **fob** except that the 'certain location' is the dockside where the goods are unloaded from the ship.

front end of the nuclear fuel cycle. Activities involving the preparation of nuclear fuel, ranging from exploration to the fabrication of nuclear fuel assemblies, and delivery of the fuel assemblies to the power plant.

fuel costs (fuel cycle costs). Those charges that must be recovered in order to meet all expenses associated with owning fuel and consuming it in the power plant.

goods. Any commodity or service which yields 'utility' to an individual or community and which must be paid for with money in a monetary economy, or with barter or compensation in a non-monetary economy.

government or national bank. A bank that works closely with its country's government to implement the monetary policy of the country by regulating the banking system and controlling the supply of money and credit so as to help promote the public goals of economic growth and high employment with a minimum of **inflation**.

grace period. The period of time between disbursement of the first loan instalment to the buyer and the first repayment made by the buyer (**interest** may be paid during this period).

gross capacity. Corresponds to the electric output at the terminals of the generator sets in a power generating station. It therefore includes the power taken by the station auxiliaries and the losses in the transformers that are considered integral parts of the station.

guarantee. An assurance of quality, performance and/or minimum working life of a product under specified working conditions.

indirect costs. The costs of engineering, construction and management services.

inflation. The general increase in prices of goods and services in a market economy that results when the availability of money rises faster than the availability of the goods and services on which it is spent (inflation does not include **real escalation**).

interest. The charge for the use of borrowed money.

interest during construction (IDC). The accumulated money disbursed to pay off **interest** on the capital invested in the plant during construction. Associated with every project are financial costs related to the use of capital. Money borrowed or committed for project implementation must eventually be paid back or recovered, with **interest**. A generic term in wide use is **allowance for funds used during construction (AFUDC)**, which includes the **IDC** as well as certain brokerage fees and other expenses related to the procurement of the loans.

interest rate. The interest rate on a loan is the percentage stipulated in the loan contract. It may be expressed as a fixed rate, i.e. an interest rate that is constant over the duration of the loan, or as a variable or floating rate, i.e. an interest rate that is recalculated at fixed intervals (for instance every six months). Variable interest rates consist of a base rate (such as the six month LIBOR) plus a margin or spread. Market rates or world rates reflect the terms of borrowing at any given time in private capital markets. Market rates are usually differentiated as long term rates, i.e. the current rates payable on financial instruments, such as bonds, having maturities of more than one year, and short term rates, i.e. the current rates payable on financial instruments maturing in one year or less. The real interest rate is the interest rate adjusted so as to account for changes in the price level.

leasing. A means of conveying property to another for a definite period in consideration of periodical compensation; e.g. an **NPP** conveyed to a utility from a **consortium** of banks.

levelized discounted electricity generation costs (LDEGC). Costs calculated by assuming that the **present worth** value of all revenues produced by the electricity generated (price at the levelized cost of the kilowatt-hour) equals the present worth value of all expenditures incurred in the implementation and operation of a plant.

life. (1) *Economic:* That period of time after which a machine or facility should be discarded or replaced because of its excessive operational cost or reduced profitability;

(2) *Design*: That period of time after which a machine or facility can no longer be repaired in order to perform its design function properly.

load factor (LF) (in %)**.** LF = $(E/E_m) \times 100$, where E is the net electrical energy (MW(e)·h) produced during the reference period under consideration, and E_m is the net electrical energy (MW(e)·h) which would have been produced at maximum net capacity (MW(e)) under continuous operation during the entire reference period.

load following capability. The unit's ability to meet the changing (increasing or decreasing) load requirements of the system.

loan repayment schedule. Time schedule agreed upon for repayment of a loan. It may include equal payments throughout the amortization period or unequal payments which increase either monotonically or by step.

marginal costs. The cost of one additional unit of production, activity or service.

maturity. For a loan, the date at which the final repayment of principal is to be made. Short term loans have an original maturity of a year or less; medium and long term loans have an original maturity or an extended maturity of more than one year.

maximum net capacity. The maximum net power that could be produced under continuous operation (15 hours or longer) with the generating unit or station running and with adequate fuel stocks of normal quality.

net capacity. Corresponds to the electrical output at the station outlet terminals, i.e. after deducting the power taken by station auxiliaries and the losses in the transformers that are considered integral parts of the station.

nominal discount rate. The **discount rate** that includes the effects of **inflation** (refer to Eq. 6).

nominal escalation. The rate of price increase for goods and services, including the effects of general **inflation** and **real escalation**.

nominal interest rate. The actual **interest rate** stated in a loan agreement. It allows for the effects of **inflation**.

nuclear fuel. Fissile and/or fertile material for use as fuel in a nuclear reactor.

nuclear fuel cycle. The steps in the process of supplying fuel for nuclear reactors. These include mining, uranium refinement, uranium conversion, uranium enrichment, fabrication of fuel elements, their use in a nuclear reactor, chemical processing to recover remaining fissile material, re-enrichment of the fuel, fabrication into new fuel elements, and waste storage.

nuclear fuel reprocessing. The processing of **nuclear fuel** (material) after its use in a reactor in order to recover valuable material and to remove fission products.

nuclear island (NI). That part of an **NPP** which incorporates all equipment, systems, installation and control and other relevant hardware installed within the reactor and reactor auxiliary buildings. The boundaries of the NI are normally defined as being one metre outside the external boundaries of the above mentioned buildings in the case of piping and two metres for cables.

nuclear power plant (NPP). A nuclear reactor or reactors together with all structures, systems and components necessary for the safe generation of electricity and/or heat.

nuclear steam supply system (NSSS). That part of an **NPP** which incorporates the nuclear heat source, the heat transfer equipment, the heat transport system and other systems directly connected to the NSSS. It may also include some I&C equipment and reactor protection systems.

operation and maintenance (O&M) costs. All non-fuel costs, such as the direct and indirect costs of labour and supervisory personnel, consumable supplies and equipment, outside support services, and (if applicable) moderator and coolant make-up and nuclear liability insurance. O&M costs are made up of two components: fixed costs (those costs which are invariant with the electrical output of the plant) and variable costs (those non-fuel costs which are incurred as a consequence of plant operation, e.g. waste disposal costs).

opportunity costs. The value of benefits sacrificed in selecting a course of action among alternatives, the value of the next best opportunity foregone by deciding to do one thing rather than another.

overhead. A cost or expense inherent in performing an operation, i.e. engineering, construction, operating or manufacturing, which can not be identified with a specific part of the work, product or asset and, therefore, must be allocated on some arbitrary basis believed to be equitable, or handled as a business expense independent of the volume of production.

overnight costs. Construction costs at a particular point in time, i.e. assuming instantaneous construction (see **fore costs**).

owner's costs. All of the costs borne by the owner which are associated with construction of an **NPP** but which are not a part of the base construction, supplementary or financing costs, e.g. land, project oversight, operator training, system turnover activities, licence fees, taxes, etc. Owner's costs are a part of the **TCIC**.

pay back period. (1) Regarding an investment, it is the number of years (or months) required for the related profit or saving in operating costs to equal the amount of the investment. (2) The time period over which a machine, facility or other investment produces sufficient net revenue to recover its investment costs.

present value (present worth). Employing present value, present worth or discounting is a mathematical process by which different monetary amounts can be moved either forward or backward from one or more points in time to a single point in time, taking account of the '**time value of money**' during interim periods.

price. The monetary value of a resource, commodity or service.

quality assurance. Planned and systematic actions necessary to provide adequate confidence that an item or facility will perform satisfactorily in service.

quality control. Quality assurance actions which provide a means to control and measure the characteristics of an item, process or facility, in accordance with established requirements.

real discount rate. The **discount rate** that excludes **inflation**.

real escalation. The annual rate of price increase that is net of general **inflation**. This can result from resource depletion, market forces, or technology evolution.

reliability. The ability of a device, system or facility to perform its intended functions satisfactorily for a specified time and under stated operating conditions.

reprocessing of spent fuel. The chemical recovery of the uranium, plutonium and certain fission products remaining in spent nuclear fuel elements.

reserve margin. A measure of the generating capacity that is available over and above the amount required to meet the system load requirements.

reserves. A country's international reserves comprise its holding of monetary gold and special drawing rights, its reserve position in the International Monetary Fund (IMF), its holdings of foreign exchange under the control of monetary authorities, its use of IMF credit, and its existing claims on non-residents that are available to the central authorities. Reserves are also expressed in terms of the number of months of imports of goods and services for which payment could be made by the country.

risk. There is risk in an activity when there is a range of possible outcomes which could flow from an event or decision. Risk may be evaluated quantitatively when objectively known probabilities can be attached to these outcomes.

salvage value. The market value of a machine or facility at any point in time. Normally, an estimate of an asset's net market value at the end of its estimated life.

sensitivity analysis. An analysis of the effect on the solution of a mathematical problem as parameters of the problem are varied.

sinking fund. (1) A fund accumulated by periodic deposits and reserved exclusively for a specific purpose, such as retirement of debt or replacement of a property. (2) A fund created by making periodic deposits (usually equal) at compound interest in order to accumulate a given sum at a given future date for some specific purpose.

specification. A written statement of requirements to be satisfied by a product, a material or a process, indicating the procedure by which it may be determined whether the specified requirements are satisfied.

spent fuel. Nuclear reactor fuel elements that have been irradiated in a reactor and have been utilized to such an extent that their further use is no longer efficient.

spread. The difference between a reference rate used to price loans and the rate at which funds are lent to final borrowers. A widely used reference rate is the LIBOR, which is the rate at which banks participating in the London market are prepared to lend funds to the most creditworthy banks. Another reference rate is the US prime rate.

supplementary costs. Costs incidental to constructing a power plant but not part of the base construction cost are referred to as supplementary costs, e.g. spare parts, contingencies, insurance. Supplementary costs are a part of the **TCIC**.

terms of trade. The ratio of a country's average export price to its average import price. A country's terms of trade are considered to improve when this ratio increases and to worsen when it decreases, i.e. when import prices rise at a relatively faster rate than export prices.

time value of money. The effect of time on the value of money.

total capital investment costs (TCIC). The total costs incurred throughout a project schedule, including escalation and **interest** charges up to commercial operation of the power generation facility.

total plant costs. Costs which include the **TCIC,** the **O&M** costs, the **fuel cycle** costs and the technology transfer costs during the economic life of the plant.

trade balance. The difference between merchandise exports **fob/fas** and merchandise imports **fob/fas**.

warranty. A written guarantee of the integrity of a product or its performance and of the maker's responsibility for the repair or replacement of defective parts.

working capital. The capital necessary to sustain operations.

yield. The ratio of return or profit to the associated investment, expressed as a percentage, usually on an annual basis.

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